METAL INDUSTRY

11 APRIL 1958

Industrial Health

APPOINTED in 1955 to advise on further development of industrial health services in working places covered by the Factories Acts, the Industrial Health Advisory Committee has undertaken two pilot surveys—the first to cover the factories in a particular area and the second, those in an industry with known health hazards. Halifax was chosen for the first survey and a report embodying the Committee's findings and recommendations has just been published. The second survey has covered the pottery industry in Stoke-on-Trent and that survey team is now preparing its report.

The Halifax team visited all the 760 factories in the area which together employed a total of 28,699 manual workers and data were obtained on all environmental factors affecting health. They found that 81 out of the 797 factory buildings were structurally unsatisfactory; that the washing facilities in 267 factories were not up to standard; that 224 factories were unsatisfactory as regards cleanliness; and that 201 undertakings had unsatisfactory ventilation. Lighting and sanitary provisions were generally good as were also canteen or meal facilities. In a considerable number of factories existing first-aid arrangements were inadequate. No unsuspected health hazards were discovered, but the Committee points out that the widespread use of industrial solvents appeared to reveal a possible hazard and they suggest that there should be a general review of arrangements for carrying out sampling of atmospheres in those sections of industry where dust, fumes or gas are thought to be a hazard.

An overall assessment of the situation shows that in 108 workplaces (6,399 workers) the assessment was good; in 490 workplaces (17,608 workers) it was satisfactory; and in 199 workplaces (4,692 workers) it was unsatisfactory. The unsatisfactory group accounts for some 25 per cent of the factories and 15 per cent of the workers. It appears from this that on the whole the smaller undertakings were worse than the larger. In them, washing facilities, cleanliness, lighting and temperatures were the worst features. In factories as a whole ventilation was the least satisfactory feature.

The question of sub-standard factory buildings, the Committee urges, should be given greater attention in the future. Washing facilities should be improved, more attractive colour schemes should be introduced into factories, and, wherever possible, a particular person should be appointed in every factory to supervise heating and ventilating. With regard to Halifax itself, the Committee feels that, in the first instance, the occupiers of those factories where 250 or more workers are employed, should be approached with a view to interesting them in the advantages of the provision or extension of medical and nursing services. (In this connection it is of interest to note that only four of the 40 general practitioners in the town work on a part-time basis serving 21 factories, and 12 full-time nurses serve 23 factories.) The general aim, the committee finally concludes, should be to improve the supervision of the health of the workers—by interview and medical examination of workers in the factory, by advice on health aspects of the working environment and by supervising the arrangements for first aid and emergency treatment.

Out of the MELTING POT

If Only

GROWING single crystals is still largely an academic occupation, but even academic developments should, whenever possible, be provided with a patent specification that will see them safely into practice when the time comes. This has been done, for example, for a method of producing high strength single crystals by growing them at or about atmospheric pressure during the hydrogen reduction of a volatile metal compound such as a halide, or during the thermal decomposition of a volatile metal compound under the same conditions. Examples of such reactions include the reduction with hydrogen of copper iodide (optimum reaction temperature 620°C.), of silver chloride (at 800°C.), or of ferrous chloride (at 730°C.), and the thermal decomposition of platinum tetrachloride, for which the optimum temperature is 800°C. The metal liberated in such a reaction is arranged to deposit on a glass or porcelain surface, the reaction being conveniently carried out in a conventional horizontal tube furnace. Under these conditions, the metal deposits from the vapour phase to form high strength rod-like single crystals. It has been found that the single crystals grown in this way have near-theoretical values of their mechanical properties. When tested by bending, such crystals are able to support elastic strains up to 1·5 per cent, which shows that their elastic limits are greatly in excess of those attainable by conventional imperfect metals. Thus, annealed single crystals of these metals, prepared by conventional methods, tested in a similar way seldom support elastic strains as high as 0·01 per cent. Because of their high strength, the rod-like single crystals grown from the vapour phase in the manner described above, are useful as strain gauge elements, springs, etc. Like other patent specifications, this one passes over in silence aspects of the subject irrelevant to its claims. As a result, it may take a little time to realize that the high strength rod-like single crystals referred to in the present specification without any mention of size, can, in fact, be nothing else than metal whiskers which, although undoubtedly rod-like, are still just as small as they have always been, and which still just as obstinately refuse to grow bigger, whatever the method of growing them.

Idling

IN spite of the frightening and increasing complexity of modern methods and means of communication—in the broadest sense of that term—a broad and detached view of the whole field is liable to leave one with the impression of progress along the line of least resistance. If this is so, it need not cause undue surprise. After all, the failing, if failing it is, of following that particular line, is a fairly common phenomenon. And why shouldn't things be made as easy as possible in, for example, the field of communication? Why shouldn't all possible information, as it becomes available, be pushed out on an increasing acreage of paper or other recording media? Why shouldn't it all be processed, reprocessed, multiplied, chopped up and about, and redistributed again and again? Why shouldn't methods of classifying it all be devised and developed into minutest detail, and then applied exhaustively to all the bits and pieces, large and small? Why, finally, shouldn't the products of all this work be stored in various forms ranging from libraries through files, microfilms and card indexes to electronic computer memories? The answer is that there is no reason why all this should not be done, unless the fact that all these activities are aimed at making things as easy as possible, be taken as a reason. That is by no means an easy thing to do. And yet, consider what is likely to happen if this reason is not taken and acted upon. Success in making things easy will undoubtedly be achieved in due course. The carefully thought-out and organized system will operate self-consistently and smoothly. So smoothly, in fact, that the work entailed will be at a minimum. The consequence of this will be—the nature of such matters being what it is—that the real useful output of the whole process will likewise be at a minimum . . . for wide is the gate, and broad is the way. . . .

Collaborative Aims

WHILE there is as yet no very clear-cut indication, there is, nevertheless, in the processes used for the production of metals, a perceptible trend towards becoming what might be described as more chemical. This trend will, in all probability, continue. What is more, once these processes will have become truly chemical they will then, also in all probability, follow the trend of other chemical processes of becoming more physical. Ultimately, there can be little doubt that the purely physical approach will be adopted. With unlimited power available, metallurgical smelting processes will become as much an anachronism as a smoky coal fire in one's sitting room. Chemical reactions will be dispensed with. The ore or other raw material, without any preparation, will be simply heated to a temperature of some thousands of degrees to dissociate it into its constituent ionized atoms, which will then be sorted out by suitably arranged electric and magnetic fields, the individual pure elements being delivered after deposition and cooling. In the meantime, however, the production of metals will still have to remain the concern of the metallurgists and, in accordance with the trend mentioned above, increasingly the concern of the chemical engineer. In view of the time and effort required to secure a working knowledge of the disciplines of metallurgy and of chemical engineering, respectively, and in view also of the current shortage of men so qualified, it must be an idle suggestion that the above trend makes desirable the availability of men qualified in both. As the alternative, there is the possibility of a much closer collaboration between the two in the design and operation of plant in which metals would not only be produced by chemical means but would simultaneously be processed into usable, at least semi-manufactured, products. There is no reason why the finished product of the chemical engineering process should become—widely separated in time and space—the raw material of some metallurgical process. Such is the trend of thought initiated by an encounter with an imaginative process and apparatus for producing metal (nickel) powder by centrifugal atomizing of nickel carbonyl and/or molten nickel and its decomposition and/or deposition in the form of a continuous strip. The atomization of the molten metal can be associated with the decomposition of the carbonyl. Undoubtedly this is imaginative food for some general down-to-earth thinking.

Skimmer

INSTITUTE OF METALS SYMPOSIUM AT BIRMINGHAM

Metallurgical Aspects of Semi-Conductors

A one-day Symposium was organized recently by the Metal Physics Committee of the Institute of Metals, at the College of Technology, Birmingham, the subject under review being "Metallurgical Aspects of Semi-Conductors." This report, prepared for "Metal Industry" by Dr. John Pratt, briefly summarizes the six short papers which were presented

ELECTRONS may exist only in discrete states of energy. In the case of a solid, the permissible electron energies occur as a characteristic spectrum or band of energy levels. The exact form of the band and the manner in which it is occupied by electrons determine the electrical properties of the material. When the electrons of highest energy (the valency electrons) occupy levels which are energetically close to vacant ones, metallic conduction is possible. On the other hand, when the valency electrons are separated from the nearest vacant (conduction) levels by a large energy gap, insulating properties result.

Semi-conductors are characterized by a completely filled valency band, separated by a moderate energy gap from an empty conduction band. At the absolute zero of temperature such a substance is a perfect insulator, but on raising the temperature, thermal excitation of electrons from the valency to the conduction band will occur to an increasing extent. The electrons transferred to the conduction band, and the positively charged "holes" thereby left in the valency band, are then both able to move easily through the crystal on applying a voltage. By moving in opposite directions in a given potential field, each type of charge-carrying particle contributes to the electrical conductivity of the material, although the mobility of the positive carriers is slightly less than that of the electrons. In this condition the semi-conductor is said to exhibit "intrinsic conduction," i.e. characteristic of the pure material; such conductivities are many orders of magnitude smaller than those of normal metals. The conductivity of a semi-conductor at any temperature is determined by the number of carriers (i.e. electrons or holes) present in the crystal. This is determined by the energy required to form an electron-hole pair, i.e. the energy band gap, and by the "lifetime" of the carriers before "annihilation" by the re-combination of pairs. Since the semi-conducting elements are four-valent, it is also possible to introduce electrons into their conduction bands by the solution of five-valent elements. The resultant material, which will be able to conduct by means of the added negative carriers, is said to show "n-type conduction." Alternatively, the addition of three-valent elements creates positive holes in the valency band of the semi-conductor and this will then exhibit "p-type conduction," i.e. the carriers are positively charged. The number of carriers, and thus the conductivity, is dependent on the amount of solute added; for practical purposes the required concentrations are infinitesimally small (a few parts per million) and must be controlled precisely.

These characteristic electrical properties have valuable applications. In recent years, semi-conductors have become of immense interest as a result of their use in the manufacture of electronic devices, the most important of which is the transistor. For transistor purposes, material of extremely high purity and crystal perfection is required. Impurity contents must be reduced to the order of about one part in 10^9, and the number and distribution of defects, such as lattice vacancies and dislocations, must be controlled also. Furthermore, the material must be obtained in the form of single crystals. The problems involved in achieving these aims are essentially metallurgical and were the concern of the present Symposium.

Semi-Conductor Materials

Present and possible future semi-conductor materials, and the problems associated with their preparation and use, were reviewed by **Professor G. V. Raynor** (University of Birmingham). So far the majority of semi-conductor devices have employed germanium as the basis material. The techniques for the preparation of transistor grade germanium are well established. Material of very high purity is obtainable by the method of zone refining; in this, the impurities are swept to the end of a solid specimen by the repeated passage of a narrow transverse molten zone along its length. Single crystals of germanium may be readily produced by a number of techniques, such as withdrawing a seed crystal at a critical rate from the surface of a melt or by controlled longitudinal freezing in a horizontal mould. Germanium devices, however, are unsatisfactory at temperatures above 60°-70°C. because of the rapid increase in intrinsic conduction which results from the low energy gap in this substance (c. 0·7 electron volts). A more satisfactory semi-conductor, from this viewpoint, is silicon (energy gap c. 1·12 electron volts), but the preparation of a suitable grade of this element is much more difficult than in the case of germanium. The high melting point (1,420°C.) of silicon greatly increases the problems of finding inert refractory materials and of avoiding contamination in general.

Silicon Crystals

The purification and growth of silicon crystals were described by **J. M. Wilson** (Standard Telecommunications Laboratories Ltd.). In reducing oxides of silicon to obtain the element, many less stable oxides present in the raw material are reduced also, and purification of the silicon so produced is difficult. Zone refining is unsatisfactory, as some of the important impurities, e.g. boron and phosphorus, are not effectively removed by this treatment. It is necessary to use chemical methods of purification. Past methods have generally involved the preparation and subsequent decomposition, on heated tungsten or tantalum filaments, of various halides of silicon; the intermediate products were given purification treatments. However, some impurities are still carried over in such reaction, and there is also a danger of contamination from the various reagents and other materials involved in the multi-stage procedures. It is preferable to produce the pure material and convert to a single crystal directly, without intermediate cleaning processes of dubious value. The purity of all materials involved should be comparable with that required of the semi-conductor. Since gases are more readily obtained in a pure condition than is material in other states, gaseous types of reaction are preferable for purification purposes. In the speaker's laboratory the method adopted is to convert silicon first to the tetrachloride ($SiCl_4$) and then to the stable hydride, silane (SiH_4). This is then decomposed to give very pure silicon and hydrogen, by heating above 500°C. Decomposition, giving a massive deposit of silicon, is carried out on a pure silicon surface so that the risk of contamination by alien filament material is removed. The great advantage of this cycle is the complete elimination of the many elements not forming volatile hydrides; boron is completely removed by this treatment. Single crystals are grown by withdrawing seed crystals from a molten pool of this material. The possibility of contamination by refractory containers is avoided by the use of the "floating zone" technique. A small pool of molten silicon, in contact only with its own solid phase, is maintained in position by its surface tension. To help stabilize the molten zone in this case, an electromagnetic field is also employed (i.e. the principle of levitation melting).

The elements silicon and germanium, occurring in Group IV of the Periodic Table, have covalent bonding and crystallize in the diamond cubic structure. Analogous structures may be obtained by combining, in equi-atomic proportions, a metal from Group III with a metalloid from Group V, or similarly by the use of elements from Group VI. The resulting compounds, e.g. AlSb, GaAs, InSb,

PbTe, PbSe, Bi_2Te_3, etc., are intrinsic semiconductors. They exhibit various energy gaps and, therefore, provide a choice of materials of very specific semi - conductor characteristics for special purposes. Further controlled modification of energy gaps to meet given requirements may be possible as a result of the mutual solubility exhibited by some of these compounds. With semi-conductors of this type, the problems of preparing single crystals of very high purity are similar to those encountered with silicon or germanium. A major additional problem in this case, however, is the maintenance of the exact stoichiometric compound composition. Deviations from stoichiometry are equivalent to contamination by impurities, thus losses during melting and segregation during freezing must be avoided.

Preparation of Compounds

The preparation of semi-conductor compounds was described by **W. D. Lawson** (Royal Radar Establishment). Before alloying, the components are individually purified by a three-stage process, each stage being repeated several times. Filtration, under a hydrogen or inert gas atmosphere, first removes those impurities which tend to form a surface scum. This is followed by the removal of volatile impurities by repeated distillation, either *in vacuo* or preferably in a stream of hydrogen. Finally, the elements are zone-refined. The separation of the volatiles before the final stage is essential, since they cannot be removed by zone refining; this is because they are returned to the purified material via the vapour phase. During these treatments, the materials are contained in crucibles of very pure silica or graphite-coated silica. Most of the elements of interest may be purified by this procedure. Selenium, however, is not susceptible to zone-refinement, since it solidifies in an amorphous form. It is purified, therefore, by the formation and decomposition of selenium hydride. Hydrogen is bubbled through molten selenium at 650°C., and the H_2Se formed is decomposed at 1,000°C. in a silica chamber. The selenium is then melted directly into a crucible within the the decomposition chamber. Purification by a factor of 10^4 is obtained by a single cycle of this type.

The purified elements are stored *in vacuo* until used for compound preparation. In the separation and weighing of the components for this purpose care must be taken to maintain purity. The most satisfactory method is to melt off the required amounts from more massive pieces. The compounds are then formed by melting together the elements in the appropriate proportions or, in some cases, by diffusing a volatile element into one less volatile through the vapour phase. A protective hydrogen atmosphere, removed before freezing the compound, is employed during these alloying procedures. At the very high temperatures necessary to melt some compounds, extremely high vapour pressures may be set up by the volatile components. Special high-pressure vessels, e.g. of thick silica, must be employed in such cases. Small closed systems may be used to prevent losses when very volatile elements are involved.

The maintenance of stoichiometry is the greatest problem in the preparation of compound single crystals. Composition changes during mixing or growing from the melt may be prevented by using a reservoir of the volatile component, held at the appropriate temperature to maintain the equilibrium vapour pressure over the molten compound. Growth of satisfactory single crystals from the melt is frequently prevented by the non-coincidence of the stoichiometric composition with the alloy of maximum melting point, i.e. the composition which separates from the melt. This gives crystals containing excessive numbers of carriers, and thus not of transistor quality. A solution to this problem has been found in the growth of crystals directly from the vapour phase, the composition being controlled by adjusting the vapour pressures of the components held in neighbouring reservoirs. Using this technique, PbSe crystals were obtained, containing 100 times fewer carriers than the best grown from the melt. The method has the advantage of involving no moving parts, but exceptionally accurate temperature control is essential. Since the growing crystals are supported on only one face, they are free from restraint and may, therefore, be expected to have very low dislocation densities. Furthermore, since deposition from the vapour can be achieved at lower temperatures than from the melt, the concentration of vacancies and other defects will be lower also. Growth from the vapour is likely to become of increasing importance. The main difficulty is the growth of crystals of reasonable size, since growth from the vapour tends to favour small scale crystallization; techniques are being developed to overcome this.

The electrical properties of semi-conductors are greatly influenced by the presence of lattice vacancies, interstitial atoms and dislocations. The numbers, mobilities and lifetimes of carriers are modified markedly by deformation. The influence of dislocations may be directly due to the extra unpaired electrons resulting from broken bonds; 10^5 dislocations per cm^2 results in numbers of carriers comparable with thermal excitation. Alternatively, because of their strong interaction with solute atoms, they may affect the conductivity through their influence on impurity distributions. In this way, as a result of the considerable range of such solute-dislocation interactions, even fewer dislocations can still exert a significant influence. Crystals grown from the melt in moulds are subjected to thermal strains behind the liquid-solid interface, and these can cause slip and thus introduce dislocations. This effect may be reduced by using "soft mould" techniques, and by the control of the shape of the interface by means of the radial thermal gradients. Further improvements result from avoiding the use of the mould by withdrawing a seed crystal from the surface of the melt, or by the use of a floating zone technique. Even when free from restraint, growth from the melt always gives crystals with lineage structures (longitudinal arrays of dislocations), so that most satisfactory of all is probably the method of growth from the vapour. Growth of crystals of selected dislocation densities is possible by the use of chosen seed crystals. The difficulty of maintaining crystal perfection increases when dealing with solid solutions between compounds because of the differences of lattice parameters involved.

Dislocations

Because of their effect on the electrical properties, the control of the concentration and distribution of dislocations in semi-conductor crystals is of great importance, and the remaining contributions to the Symposium were concerned with the introduction, detection and behaviour of dislocations in these materials. Most studies of dislocation behaviour rely on surface etching to locate these imperfections, although in few cases has it been established that the surface etch pits correspond exactly with the dislocation density in the interior. Previously, exact correspondence had been proved only for the case of edge-type dislocations in germanium; the number and distribution of pits were compared with the dislocation densities expected, on theoretical grounds, to be present in low-angle grain boundaries and deformed crystals.

Studies of germanium single crystals deformed by twisting were described by **W. Bardsley** and **R. L. Bell** (Royal Radar Establishment). This treatment introduces screw dislocations, and the numbers of etch pits observed corresponded reasonably with the theoretically expected numbers. A number of etch-pits, present in the as-grown crystals and unaffected by deformation, could not be accounted for, however. Extra information was deduced from the shape of the etch-pits which, in this case, was found to depend on the angle of emergence of the dislocations. Crystals deformed at various temperatures were examined. The observed distributions of dislocations indicate that they are readily able to re-arrange themselves at temperatures above approximately 600°C. Only below this temperature were they found to remain in the slip planes; above it, regular polygonal arrays were seen. The dislocation patterns observed in many as-grown crystals correspond to the lower temperature type of arrangement, suggesting that they are formed at relatively low temperatures.

More direct observations of disloca-

tions in germanium and silicon were reported by **R. Phillips** (A.E.I. Research Laboratories). These were made by means of the transmission electron microscopy of thin films; the specimens were slices cut from single crystals of these materials with a diamond wheel and ground, polished, and finally etched to the required thinness. Etch pit counts showed dislocation densities in the as-grown crystals to be approximately $10^4/cm^2$, so that the likelihood of observing one in the field of the electron microscope was very small. Observations were, therefore, made after increasing the dislocation density by indentation, in vacuum, on a hot-hardness testing machine. The variation, with temperature, of the dislocation pattern observed agreed with the behaviour reported in the previous contribution. At 700°C., the mobility of dislocations in germanium was sufficient to permit considerable re-arrangement during the period of indentation (30 sec.). Deformation at temperatures below this gave an irregular dislocation pattern; the density was approximately 10^9 dislocations per cm^2. The amount of re-arrangement increased with testing temperature until a completely regular hexagonal polygonized structure was produced at 800°C. These results only apply strictly to the complex stress systems arising from indentation, but investigations are being made of the temperature dependence of dislocation mobility in germanium for simpler stress systems. The dislocation arrays produced in the present experiments were also studied on the more macroscopic scale by means of etch-pit techniques. Similar electron microscopy studies are being made on the semi-conducting compound Bi_2Te_3.

A study of the influence of applied stress and temperature on the deformation characteristics of another semi-conductor compound was described by **J. W. Allen** (Services Electronics Research Laboratory). The dislocation density in as-grown crystals is low (c. $100/cm^2$), and at low temperatures and stresses it is suggested that deformation is controlled by the rate of diffusion of the impurity atoms to which these dislocations will tend to be locked. In this condition, the material is hard and brittle. The movement of the dislocations, under the influence of applied stress, will lead to their interlocking, and the formation thereby of sources for the generation of further dislocations. When such sources begin to act, and so provide large numbers of dislocations free from solute atom restraint, the material will soften and large deformations will be possible. By increasing the rate of movement of the original dislocations, the time to establish suitable sources is reduced. Thus, the onset of plastic behaviour is encouraged by increases of temperature and of applied stress. This theory, which is in complete contrast to that advanced by Seitz, is supported by the metallographic observations on dislocation (etch-pit) patterns. Completely irregular arrays are observed during the early stages of deformation, and well-developed slip lines were only in evidence at much later stages, possibly only after the formation of suitably orientated sources.

Decoration Techniques

Finally, **J. W. Mitchell** (University of Bristol) described the use of decoration techniques for the study of structural defects and deformation of crystals. The decoration of dislocations, by causing precipitation to occur upon them, renders the array in the interior of the crystal directly visible when illuminated with either normal or infra-red light. The relation between the internal dislocation arrangement and the surface features can then be seen. Unless exact correspondence between etch-pits has been proved, surface studies alone are unreliable. In most cases at present it is not possible to make such studies directly on semi-conductors, but observations relevant to them may be obtained by the investigation of silver halides. These provide an appropriate model, but one which is simpler and more amenable to study by this method. Thus AgBr or AgCl provide suitable models for the behaviour to be expected in the semi-conducting compounds PbS or PbSe. The dislocations in AgBr may be decorated, by the precipitation of silver simply by exposure to light, and their behaviour may be readily observed in static or dynamic experiments, i.e. during deformation or heating. The decoration method may be applied directly to silicon; the dislocations are decorated with copper and examined under infra-red illumination. In the silver halides and in silicon, one to one correspondence between etch pits and emergent dislocations was found. During deformation, or as a result of thermally induced stresses, dislocations are readily introduced into the crystal from the surface, and large densities may arise without the existence of internal sources. Thus, the growth of dislocation-free crystals requires very careful control of thermal gradients and other conditions; stable crystal faces should be perpendicular to the growth direction and aligned with any constraining surface. AgBr or AgCl can each be prepared as single crystals free from dislocations, but mixed crystals of these always exhibit very stable substructures (arrays of dislocations). This suggests that mixed semi-conductor crystals will always have a higher dislocation density than elements or individual compounds, with significant effects on their electrical properties, which confirms the observations on the solid solutions between semi-conductor compounds reported by an earlier speaker.

The range of operation of infra-red microscopy must be extended to longer wavelengths before the direct study of the antimonides or of germanium is possible by this method. Meanwhile, electrical conductivity measurements have been employed to deduce the orientation of dislocations in certain crystals of germanium (**Hogarth,** Royal Radar Establishment). Local variations of conductivity, associated with the presence of a dislocation, were measured by means of micro-probes moved in half-micron intervals over the surface of the specimen. Correspondence with etch-pits was observed.

Research of the type reported at the Symposium is of paramount importance in the solution of the problems of semi-conductor technology, but also has considerable impact beyond this. Thus, the deformation studies on semi-conductors make a particular contribution to dislocation theory in general. Similarly, techniques such as zone refining, the use of floating zones to avoid refractory problems, or the use of electron bombardment to obtain intense localized heating are proving valuable for wider application.

Correspondence

Correspondence is invited on all subjects of interest to the non-ferrous metal industry. The Editor accepts no responsibility either for statements made or opinions expressed by correspondents whose letters appear in these columns

TO THE EDITOR OF METAL INDUSTRY

Fuel Efficiency

SIR,—I have read with interest your shortened version of the Paper on electric furnace developments given to the Birmingham Metallurgical Society by Mr. P. F. Hancock. I was particularly interested in his comparison of the high frequency and normal frequency coreless induction furnaces. In the course of the comparison he states: "Elimination of the costly frequency changer results in the capital cost of the mains frequency installation being only one-half to two-thirds of that of a high frequency furnace of equivalent capacity and power rating." I entirely agree with this statement, but I think the attention of your readers should be drawn to the fact that the high frequency furnace has a much higher output per shift than the mains frequency furnace of equivalent capacity and power rating. This is due to the fact that the mains frequency furnace has a lower load factor during the melting cycle and employs a larger furnace to reduce the electro-magnetic stirring effect. For a given output, which is what matters most to the users, the two types of furnaces are not widely different in price.

Both types of furnace have their uses, but in comparing the cost of one with the other, I think the above facts should be taken into account.

Yours, etc.,

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Research Progress

Nucleation of Voids During Diffusion

BY RECORDER

THE essential feature of the so-called "Kirkendall effect," first reported by Smigelskas and Kirkendall, lay in their discovery that when interdiffusion occurs between two metals, A and B, the diffusion rate of A in B need not equal that of B in A. As a consequence, interdiffusion can give rise to an unequal diffusion flow across the boundary separating the two metals, and if A diffuses into B faster than B into A, a marked interface between A and B will apparently move into the metal A. In addition, the nett loss of atoms on the side of the interface occupied originally only by metal A causes the formation of vacant lattice sites in excess of the normal equilibrium number. The supersaturation of vacancies may be relieved in two ways, either by diffusion of vacancies to vacancy "sinks," or by the coalescence of vacancies into voids which, under favourable circumstances, may grow to macroscopic dimensions. Since the excess of vacancies is generated in the region where the nett transfer of material is greatest, the voids will be created on the side of the interface originally occupied by the fastest diffusing metal (metal A above).

Although these general principles have been established and verified by experimental evidence, different workers have obtained results that appear to be inconsistent when more detailed points are considered. For instance, although voids are found in the expected position relative to the interface, the width of the zone containing voids varies considerably even in duplicate experiments, and does not seem to be influenced by the diffusion processes which are controlling vacancy supersaturation. The sizes of the voids also vary in an irregular manner, and the relationship between the number of voids and the diffusion conditions is obscured by unexplained discrepancies.

Most of the anomalous features described are linked directly or indirectly with the way in which the voids are nucleated and, in the hope of resolving some of these problems, R. S. Barnes and D. J. Mazey, of the A.E.R.E., Harwell, have carried out experiments on void nucleation. Their general approach, described in a recent Paper,[1] was to apply hydrostatic pressure to specimens consisting of alternate layers of copper and nickel under conditions which would normally lead to the formation of voids in the copper. The specimens were made by pressing together 24 copper and 25 nickel sheets, arranged alternately, for 10 min. at 950°C. under a pressure of 3,000 lb/in^2.

In preliminary experiments a sandwich sample of this type was placed in a Stellite die, which was closed with Stellite plungers. This arrangement was inserted into a larger, nickel-chromium die, also fitted with plungers that could be used to transmit a load to the diffusion sandwich. The required pressure was applied and the temperature of the whole assembly raised to 1,000°C., being maintained at this value for 4 hr. Owing to inadequate control, the applied pressure varied considerably over the period of the experiment, but all three levels of pressure used — 5,330-8,000 lb/in^2, 2,660 - 4,000 lb / in^2, and 1,300-2,000 lb/in^2—prevented the formation of voids in the specimens.

Further, more refined tests were made with sandwich samples, the pressure being applied hydrostatically by pressurizing with pure argon a stout Nimonic tube containing the specimen. With this apparatus, steady pressures up to 2,500 lb/in^2 could be maintained without difficulty. Two types of specimens were tested: the first was prepared as described earlier—that is, with only a very short heat-treatment sufficient to weld the alternate layers together. The second type, however, was annealed for 4 hr. at 1,000°C. *in vacuo* after welding. This latter treatment produced diffusion voids, so the effects of pressure could be studied on specimens already containing, or free from, voids.

As might be expected, the behaviour of specimens annealed at 4 hr. at 1,000°C. under hydrostatic pressure depended on whether or not voids were present prior to this test. The effects were assessed by measuring the number of voids present in the sample, and also by density measurements. For specimens not pretreated, increasing the hydrostatic pressure progressively reduced the number of voids formed by diffusion from just over 800 per cm. of interface at zero pressure to 400 and 100 per cm. at about 600 and 1,000 lb/in^2 pressure respectively. At pressures exceeding about 1,300 lb/in^2, the number of voids formed was negligible. In specimens already containing voids before the pressure-diffusion treatment, higher pressures were required to eliminate voids, so that a pressure of 1,300lb/in^2 reduced the number to about 350 per cm. and 2,300 lb/in^2 or more was needed before the number of voids was negligible. The density measurements gave results in accord with those obtained by direct observation of the changes in void concentrations.

Barnes and Mazey next considered the implications of the above results. They suggest, following Seitz,[2] that a void can be held at a constant size of radius R by an external pressure P if

$$P+2\gamma/R=kTN \ln (c/c_o)$$

where γ is the surface energy/unit area of the void, k is Boltzmann's constant, T the absolute temperature, N the atomic density and c and c_o are the vacancies/unit volume actually present and present under equilibrium conditions respectively. The void will, therefore, tend to collapse if P exceeds a critical value, though the rate of disappearance will presumably diminish when this process alters appreciably the values of R and c. Barnes and Mazey develop this idea to cover the case of a void forming at a nucleus, and substitute for P in the equation above a new value P' the external pressure below which a void can grow on a nucleus of radius R when a supersaturation of vacancies c' is present in the region of the nucleus. If the external pressure is greater than P', void nucleation will not occur on nuclei with radii less than R and if the pressure is greater than $k\ TN \ln (c'/c_o)$ voids will not be formed even on nuclei of infinite radius.

Taking reasonable values of γ (10^3 ergs/cm^2) and R (5×10^{-4} cm.) for samples annealed *in vacuo* for 4 hr. at 1,000°C., the ratio c'/c_o can be calculated from the observation that voids in specimens so treated disappear if the samples are subjected to pressures of 2,300 lb/in^2 or over at 1,000°C. The value obtained indicates a vacancy supersaturation in the vicinity of the voids of 1·1 per cent. By assuming that this supersaturation exists throughout the period of the diffusion treatment, it is now possible to estimate the size of nuclei on which the voids formed, since the critical pressure for preventing void formation in untreated samples was 1,300 lb/in^2. A lower limit to the radius of the nuclei can also be found for the case where $P'=0$, since at the supersaturation level of 1·1 per cent nuclei with radii smaller than this critical value could not assist in forming voids. The range of radii given by these two calculations is $1{\cdot}2-2{\cdot}8\times10^{-5}$ cm. Microscopic examination of the specimens showed that small inclusions lying at the copper-nickel interfaces had radii up to 6×10^{-5} cm. and the authors concluded that it was upon these inclusions that void nucleation occurred. They are also able to attribute the variations in the results of other workers to differences in the size and distribution of inclusions suitable for void nucleation.

References

[1] R. S. Barnes and D. J. Mazey; *Acta Met.*, 1958, **6** (1), 1.

[2] F. Seitz; *ibid*, 1953, **1**, 355.

LARGE CONTINUOUS CASTING INSTALLATION FOR TOUGH PITCH COPPER

Casting Rolling Slabs

FOR the commercial production of continuously cast tough pitch copper cakes for rolling sheet, a unit that has some unusual features has been installed by American Smelting and Refining Company at its Perth Amboy, New Jersey, refinery. This new plant permits casting of copper cakes up to 25 ft. long by 36 in. wide and weighing over 7½ tons. Capacity of the casting installation is in excess of 160 tons of copper per 8 hr. shift.

With the longer lengths made available by this plant, copper rolling mills will be able to increase their production, with a consequent gain in plant efficiency and reduction in operating costs. Moreover, metal cast by the new method is unusually sound and dense, and has a surface uniformity which is ideal for rolling. These factors all contribute to improvement of rolled copper sheet and strip.

The Asarco casting technique uses a small, "bottomless" water-cooled graphite mould. Molten copper is poured continuously into the mould cavity, where it is cooled as it passes through the mould, and emerges from the orifice as a smooth, dense copper cake.

The mould is only 15 in. deep, but it has a heat dissipation rate of about 1,500 h.p. This is believed to be the highest heat capacity per square inch of surface of any mould ever built for either ferrous or non-ferrous casting. The design enables the mould to solidify molten copper cast at 1,150°C. at a speed of up to 20 in/min. for a 5 in. by 36 in. cake. This is equivalent to 1,150 lb/min. of copper.

The mould design eliminates the need for mould preparation compounds such as are used in conventional water-cooled copper moulds. To prevent sticking of the cast copper to the mould, and to ensure a smooth cake surface, the entire mould assembly is oscillated by a reciprocating gear. The vertical stroke is only a fraction of an inch and the variable-speed driving motor can operate up to several hundred cycles/min.

At the present time, the technique is being used on tough pitch copper—the type of copper which represents about 90 per cent of U.S. consumption. However, the versatility of the process is such that it can be used, with minor modifications, to produce cakes of oxygen-free, phosphorized, or other special coppers.

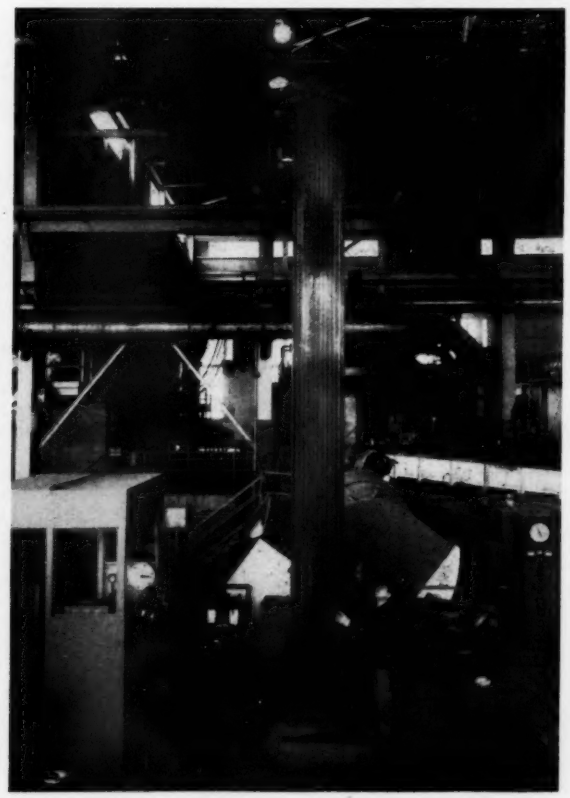
The conventional method of manufacturing tough pitch copper cakes has been to cast them in individual, water-cooled, copper moulds. The type of mould customarily used yields a cake 25 in. to 36 in. wide, 4½ in. to 7 in. thick, and 36 in. to 92 in. long. Such cakes weigh between 1-1½ tons.

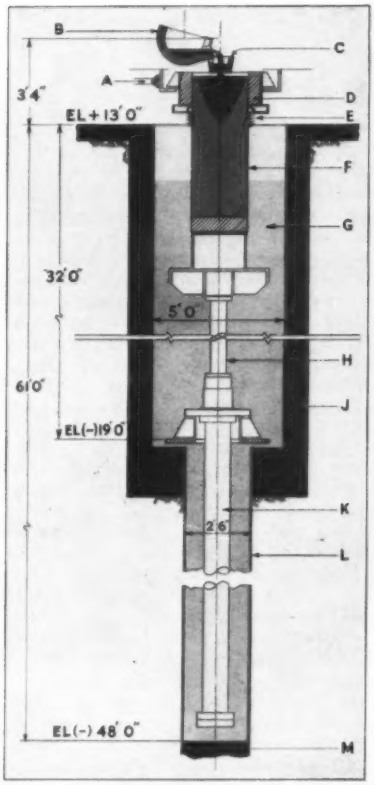
One of the limitations imposed on the size of the optimum quality cakes that can be turned out by conventional methods is that they must be vertically cast. Horizontal casting is not practicable because the quality of the cake surface, which is of paramount importance to rollers, is impaired. Vertical casting of tough pitch copper cakes more than about 37 in. deep by old batch methods is disadvantageous because of the quality deterioration experienced (e.g. from metal splashing).

However, a 37 in. length cake, even of top quality, is far from ideal for many modern rolling mills. In recent years, many mills, confronted by higher labour costs, have installed larger, faster rolling equipment. But they have not been able to utilize these modern facilities at maximum efficiency and most economically with the cake sizes available. Longer cakes, ideally only 5 in. thick, were the real need of most mills, since these permit the production of the maximum quantity

Below : Pouring tough pitch copper into the rectangular mould of the Asarco continuous casting machine

Right : Removing the rolling slab from the casting pit. The mould assembly has been swung away and can be seen at the right





A—Reciprocating mechanism. B—Ladle. C—Metal distributor box. D—Mould. E—5 Water sprays. F—Casting. G—Cooling water. H—Stainless steel ram. J—Reinforced concrete cylinder. K—Hydraulic cylinder. L—Steel casing. M—Concrete

Arrangement of installation for continuous casting of rolling slabs up to 25 ft. long

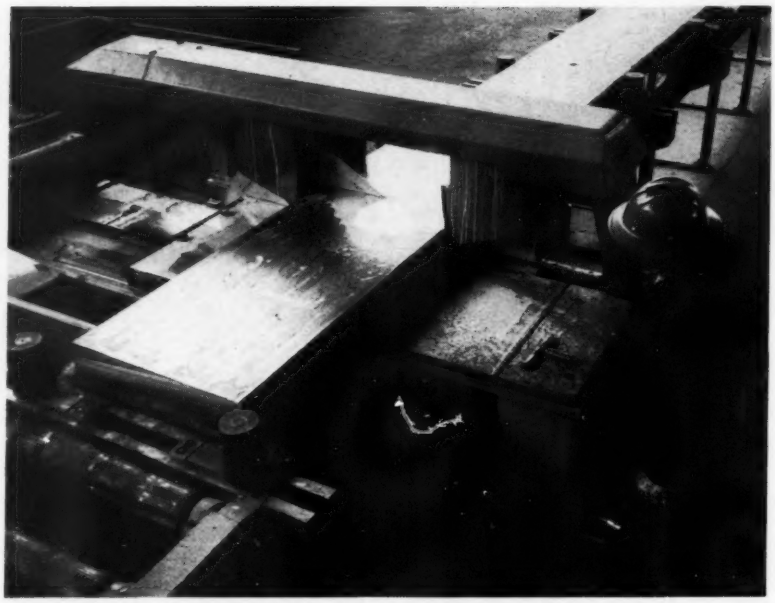
of sheet and strip per hr. with a minimum number of passes through the rolls.

The Asarco process now introduced has solved this problem, and continuous cast cakes, up to 25 ft. long, in the thin dimensions desired, can now be made in widths of 25, 30 and 36 in.

At the Perth Amboy installation, the mould is situated at ground level at the mouth of a specially constructed, 61 ft. deep, water-filled well. As the solid cake emerges from the bottom of the mould it is cooled by a series of high-speed water-spray jets. It is then lowered continuously into the reservoir of cooling water.

The cooling water is circulated by an 1,800 gal/min. pump. As one precautionary measure, a duplicate pump is installed in the system which will cut in automatically if the operating pump should fail. In addition, a 500 gal/min. emergency pump operating from an independent power source will take over in case of primary power failure. The heat dissipation capacity of the entire cooling system is rated at 5,800 h.p.

The cake is lowered into the well by a stainless steel hydraulic ram, which has a 27 ft. stroke. The rate of lowering is constant, regardless of the varying weight on the ram. The ram, and its actuating hydraulic equipment, are completely submerged in water. The withdrawal ram, rate of casting of metal, cooling system, and other vital elements of the casting shop, are electronically controlled. One operator can govern the entire casting operation from the electronic control centre located in a booth a few yards from the casting pit.



Sawing rolling slabs to length by high-speed saw. The cutting rate is 4 ft/min.

After the cake is cast, the mould is swung to one side and the 25 ft. 7½ ton cake is lifted by a 10 ton crane to a nearby platform. There it is sawn to the precise lengths which are specified by customer rolling mills. The saw, of unusual capacity, cuts through the cake at a speed of 4 ft/min.

As it is now installed, the casting shop includes two moulds, side by side. The new unit is capable of casting two cakes, at a rate of up to 20 in. each per min. simultaneously.

The cake casting unit is the second phase of Asarco's expansion at its Perth Amboy casting shop. In January, the company installed the world's largest direct arc copper melting furnace there; by June the construction of new and larger facilities for the continuous casting of copper billets will be completed.

All three operations — continuous copper melting, cake casting and billet casting—will be integrated operations. The melting furnace will provide the molten copper for cakes, billets, and, in addition, for the company's new Perth Amboy wire bar casting wheel.

The furnace has a bath capacity of 90 tons of molten copper, and is designed to melt copper cathodes at a 30 ton/hr. rate. Currently, the 8,000 kVA furnace is operating substantially in excess of rated melting capacity.

For the cake casting unit, tough pitch copper flows down a launder from the arc furnace to a 10 ton holding furnace. Metal temperature is adjusted in the holding furnace to 1,150°C. This metal flows, through a special pouring ladle, to the distributor, which ensures a smooth splash-free entry of metal into the mould cavity.

This, coupled with other design characteristics of the mould and cooling equipment, yields cake which is dense, sound, and has a surface ideally suited to the needs of rolling mills.

Temperature Control

NOW generally available, the Sifam "Pyromaxim" electronic temperature controller has a mirror scale of more than 8 in. length, which ensures legibility and accurate reading of temperatures to better than 1 per cent. The calibration complies with B.S.S.1041 recommendations and the control response is within 0·25 per cent.

The measuring galvanometer employs an Alcomax magnet surrounding a moving system which swings between spring-mounted sapphires. Automatic cold junction compensation is a standard provision. This movement and its pointer are completely free from mechanical stress or interference.

A simple electronic circuit provides the link between measurement and control which instantaneously operates an enclosed relay rated at 3 amp. and 250 V. A.C. non-inductive load.

The "Pyromaxim," a product of Sifam Electrical Instrument Co. Ltd., Leigh Court, Hr. Lincombe Road, Torquay, Devon, is available in ranges from 0-200° to 0-1,600°C., or Fahrenheit equivalents. Calibration can be made for any type of thermocouple.

CONSUMPTION — MATERIALS — MIXING — COMPACTING — SINTERING

Porous and Infiltrated Metal

By J. E. ELLIOTT, B.Sc., A.I.M.

Presented recently at a meeting of the Birmingham Metallurgical Society, this Paper discusses powder metal applications, the characteristics of the alloys, and the techniques of their production. The portion of the Paper that appears here deals largely with bearings and with the fundamentals of the process. The remainder of the Paper will appear next week.

VARYING widely in different countries, the size and development of the powder metallurgy industry have reached a point where the present general scope of commercial production is as shown in Table I. The range of products given is applicable to North America and Europe, including, of course, the United Kingdom.

It is possible to classify the products of the powder metal industry into two groups, i.e. those which are unique and, secondly, those which compete with similar products made by other methods of manufacture. The first group includes carbides, refractory metals, self-lubricating bearings, iron powder cores, filters, and special compositions, and all are materials which cannot be made by other methods of manufacture or with the same special characteristics.

The competitive type of products include sintered magnets, sintered components, and special alloys. These materials are also made by various other means, and the merits of the sintered product are that it is made either cheaper or to a higher degree of technical quality by the powder metal technique. For instance, Alnico can be made by casting, but the sintered magnet is found to have superior properties. On the other hand, sintered components are seldom of superior technical quality to those made by any other means, e.g. machining, forging or casting, and the sole merit of the process lies in the lower cost of manufacture. Special alloys are usually characterized by extremely good control of composition or purity, and in this sense are technically superior to similar alloys made by normal techniques.

It is of interest to note that, in some cases, the sintered compacts are end products in themselves whilst, in other cases, they are only intermediate products. In the case of the refractory metals and special alloys, the powder metal stage of the manufacture is followed by further metallurgical operations, e.g. swaging and rolling, and in these cases the manufacture of the sintered compact is only a phase in the full manufacturing procedure.

Full statistics of the scale of sintered bearing and component production are not available, but some information has been privately collected from various sources and is summarized in Table II. It must be emphasized that these figures are only approximate assessments and must not be regarded as accurate estimates of production, particularly in the case of the U.K.

The tremendous expansion of the industry is obvious from these figures; U.K. production has increased tenfold in the last 20 years, but expansion in the U.S.A. has been over 20 times. The most substantial expansion has taken place in the post-war years in both countries.

Two particular trends are apparent from the figures. In the first place, production 20 years ago was entirely confined to non-ferrous self-lubricating bearings; whilst this particular field has itself expanded, there has been a tremendous development in the sintered component field, particularly in the U.S.A. The same trend is apparent in the U.K., but to a much smaller degree.

Secondly, there has arisen the development of ferrous sintered parts, including both bearings and components. In 1937 virtually no ferrous parts were manufactured, but these now form a substantial proportion in both the U.K. and U.S.A. Probably about 25 per cent of current production in this country is ferrous; the corresponding proportion in the States is not known for certain, but is in excess of this level.

The 10,000,000 non-ferrous parts which are made in this country per month are estimated to consume about 150 tons of raw material and the average weight of each component works out to be approximately 15 gm. These figures emphasize that the pattern of production is that of a large number of components of relatively small weight.

TABLE I—RANGE OF PRODUCTS

1	Refractory metals, e.g. tungsten and molybdenum	
2	Carbides	
3	Magnets, e.g. Alnico and iron powder cores	
4	Self-lubricating bearings	Non-ferrous and ferrous
5	Sintered components	Non-ferrous and ferrous
6	Filters	Non-ferrous and ferrous
7	Special alloys and compositions	

TABLE II—SINTERED BEARING PRODUCTION

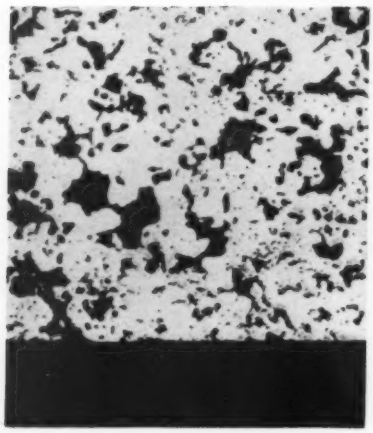
	U.S.A. (parts/month)	U.K. (parts/month)
1937	6,000,000 (Non-ferrous bearings)	Approximately 1,500,000 (Non-ferrous bearings)
1953	100,000,000 (Bearings and components; Ferrous and non-ferrous)	Approximately 7-8,000,000 (Bearings and components; Ferrous and non-ferrous)
1957	150,000,000 Components: 100,000,000 Bearings: 50,000,000	Approximately 13,000,000 Bearings: probably about 66-75 per cent Non-ferrous: c. 10,000,000* Ferrous: c. 3,0000,00

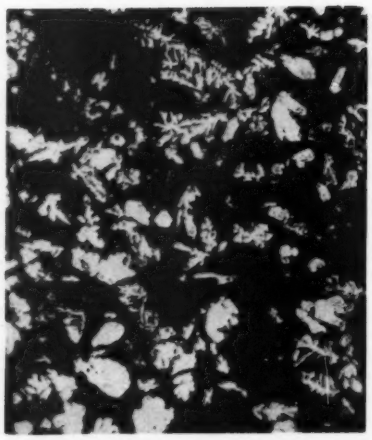
*Average powder consumption approximately 150 tons per month.

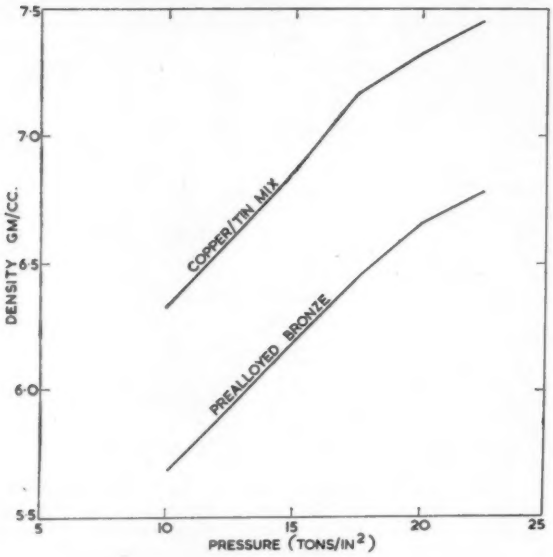
Bronze Bearings

Bronze is well known as a bearing alloy and it is logical that the material should be required in the self-lubricating form made by powder metallurgy. The essence of the self-lubricating property depends, of course, upon a substantial degree of porosity which is mutually interconnected and thus allows oil to be stored within the bearing section and to be fed through the permeable structure to the running surfaces.

Cast bearing bronzes vary in composition, e.g. tin may vary from, say, 5 to 15 per cent, and often contain other elements, e.g. lead and phosphorus. It is technically possible to reproduce these compositions by the powder metal process, but there has been a tendency to standardize upon a 90:10 composition and, in some cases, to include a portion of lead. One other addition has become very widely accepted for sintered bronze bearings, i.e. graphite. Graphite is added as powder to the powder mix and is dispersed throughout the bronze matrix.







Above left: Fig 1—Section through porous bronze bearing (x100)

Left: Fig. 2—Compressibility of pre-alloyed bronze compared with that of a copper-tin mix

Above: Fig. 3—Electrolytic copper powder (x80)

A typical average addition is 1·5 per cent (by weight).

It is, of course, impossible to disperse graphite in cast bronze, and the addition to the sintered material is unique. Two general reasons are advanced for the inclusion of graphite and they are respectively associated with the manufacturing operations and the actual performance of the bearing itself. Graphite, being a lubricant, is of assistance in the compacting operations, and it is also held to improve the lubricating characteristics of the finished bearing.

The composition of sintered bronze materials has now been standardized in various A.S.T.M., S.A.E. and British Standard specifications, and the most widely adopted composition is 90:10, containing 1·5 per cent by weight of graphite.

The microstructure of porous sintered bronze (Fig. 1) demonstrates that the pore structure is fairly irregular and that the pores open out on to the surface of the bearing rather in the form of a river estuary. Although the microstructure is a two-dimensional picture, there is ample evidence to demonstrate the high degree of interconnection of the pores.

The density of solid bronze is 8·7 gm/c.c., and self-lubricating bronze bearings are normally manufactured in the density range from 6 to 7 gm/c.c. This range corresponds with porosities from approximately 30 per cent to 20 per cent. Tensile strengths normally lie in the range 12,000 to 20,000 lb/in², and percentage elongation is usually of the order of 3 to 6 per cent. As compared with the mechanical properties of solid bronze, e.g. 40,000-50,000 lb/in² U.T.S. and 20 per cent elongation, it will be appreciated that there is a substantial reduction in properties.

Self-lubricating bearings are, by their nature, relatively small in size and are required in relatively large numbers. In addition, the materials are comparatively easily compacted and, for instance, do not require unduly high compacting pressures. Furthermore, the quality of the end product permits powders to be used which have good flow and green strength properties and, therefore, allows high speed compacting operations to be applied.

These various considerations dictate that high speed cold compacting, followed by sintering, is the best manufacturing technique.

Raw Powder Materials

In manufacturing a sintered alloy material it is possible to follow two basic courses with regard to choice of raw material. On the one hand, a pre-alloyed powder may be used or, alternatively, a mixture of the pure metal powders may be employed and alloying may be achieved during the sintering operation. It is possible, of course, to compromise and use partially alloyed powders.

Various important considerations arise when choosing the best raw material, and consideration of the respective merits can be usefully discussed according to the way in which the compacting and the sintering operations are influenced. With regard to compacting, the mechanical properties of the two types of powder mix are most important. Alloys are harder and more difficult to deform than their constituent metals, and it is to be expected that a pre-alloyed powder will be more difficult to compact than a mixture of, say, copper and tin powder. The main influence of the mechanical properties will be on the compressibility, i.e. pressure/density relationship of the material. It will be seen from Fig. 2 that the compressibility of a pre-alloyed powder is significantly different from that of a mixture of copper and tin powders. A much higher pressure is required to achieve a particular density with pre-alloyed powder.

One important consideration is that larger load capacity presses would be required to manufacture bearings from pre-alloyed bronze than from copper-tin mixtures. In addition, due directly to the higher pressures which would be involved, tool wear would be greater with the pre-alloyed powder; tool wear would also be greater because of the harder nature of the alloy particles.

With regard to sintering, the outstanding merit of copper/tin mixtures lies in the creation of a liquid phase during sintering. The tin particles melt above 232°C. and wet the copper powder particles. This process brings about intimate contact between the copper and the tin, and so ensures efficient alloying; in addition, sintering proceeds rapidly, due to the cementing action of the liquid phase. The total result is a very rapid development of sintering and alloying, associated with a rapid development of strength.

On the other hand, the sintering of pre-alloyed bronze proceeds in the absence of a liquid phase, and the development of strength is relatively slow. Longer sintering times are inevitably involved. For these reasons,

production has become firmly established upon copper and tin powder mixtures, and sintering times of short duration are common.

Copper and Tin Powders

The basic factors in the choice of powders are cost and technical quality. The qualities which are required include adequate purity, good flow, good green strength, and control of particle size, and it is very important for production purposes that the powder should be of a consistent quality from batch to batch.

The properties of the mix largely follow from those of the copper powder, and the final bearing structure is partly related to the characteristics of the copper, e.g. particle size determines pore structure. Electrolytic and atomized copper powders are used for the manufacture of bronze bearings, but electrolytic powder predominates by far. Fig. 3 illustrates the irregular, dendritic, particle shape of the latter type of powder, and explains the generally good compacting properties.

Certain properties are desirable in the tin powder, and a fine particle size is an outstanding need. This is to facilitate good dispersion of the tin in the powder mix, and permits more rapid homogenization and sintering to be achieved. The normal method of manufacture of tin powder is by atomization.

Graphite is added to the powder mix as a fine natural powder.

Powder Mixing

For high speed cold pressing, internal lubrication of the powder mix is the most suitable way of ensuring lubrication between the powder and the walls of the compacting tools. It would be difficult, for instance, to apply die surface lubrication under such conditions. The lubricants used include powdered stearic acid and various metallic stearates, e.g. zinc stearate.

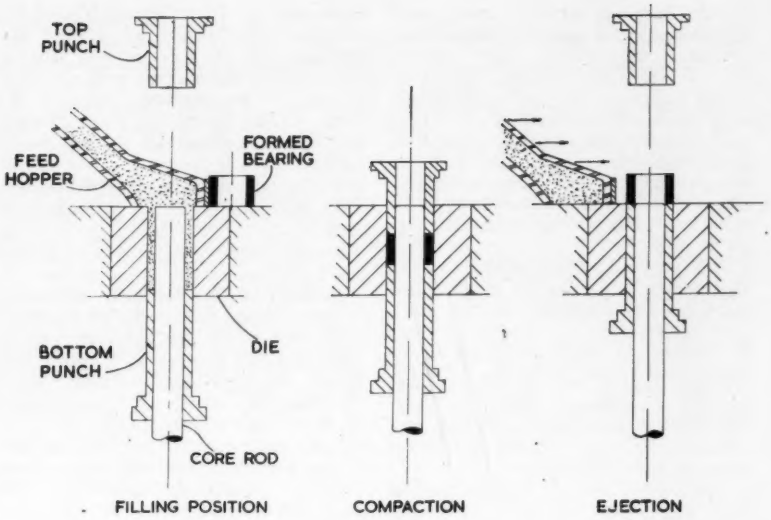
The mixing technique contrasts strongly with that practised in, say, the carbide industry. Paddle or blade type mixers are common, and the mixing times are of short duration. The contrast with the carbide mixing technique is due to the better flow of the powder mixes and the less critical requirements for the copper-tin mixture.

Compacting

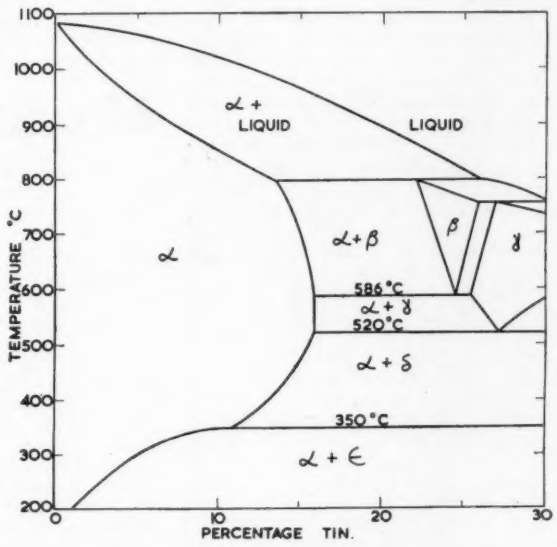
The compacting of porous bronze bearings requires moderate compacting pressures which are of the order of 10 to 30 tons/in^2.

Compacting presses are of two types, i.e. mechanical and hydraulic. The mechanical presses are operated by rotating cam movements, and double end compression is usually possible with these types of press. The load capacity of mechanical type presses is, of course, limited, and the larger types have the capacity of 40 tons, although some presses can produce 100 ton load. However, there is the advantage of high speed production, and rates of output of between 300 and 3,000/hr. are common. In such equipment the feed of powder, the forming, and the ejection of the bearings virtually becomes continuous.

Hydraulic presses are generally slower in rate of operation, but, of course, may be of greater load capacity. Loads in the range from 100 to 500 tons are usual, and it is possible to achieve rates of forming of up to 500 per hour.



Above: Fig. 4—Sequence of forming operations for compacting powder



Right : Fig. 5—Constitutional diagram of copper-tin system

Press Tools

Press tools basically comprise four items, i.e. die, core rod, top punch, and and bottom punch. Fig. 4 illustrates how these are arranged and also indicates the various punch movements involved in the sequence of the compacting operation.

The most important metallurgical problems in connection with tools are those concerned with tool wear. Wear is most severe on dies and core-rods, and the wear mechanism is one of high pressure abrasion by the metal particles against the die surfaces. The side thrust pressures can approach the compacting pressures, particularly at the ends of the formed bearing adjacent to the punches. Unfortunately, it is not possible to follow the obvious course of increasing the lubrication of the metal powder mix, since this action brings about a significant reduction in flow and green strength.

Powder forming tools essentially run at room temperature, although frictional heat may bring about a small rise in temperature. Impact conditions are normally absent and tungsten

carbide is by far the outstanding tool material, since it possesses good wear resistance and relatively low friction. However, it is not always possible to justify the cost of carbide tools unless large quantities of bearings are to be manufactured and, in these cases, high chromium-high carbon die steel is used, as well as hard chromium plate. The latter material is used both in tooling up and as a recovery process for worn tools.

Punches suffer less abrasive wear than dies or core rods, and are required mainly to transfer the compacting load.

Sintering

It has already been mentioned that the use of copper-tin mixtures allows liquid phase sintering to operate, and permits the rapid development of alloying and sintering.

The copper-tin alloy diagram (Fig. 5) indicates that a number of intermediate solid solutions are formed between copper and tin, and the normal condition of a 90:10 bronze is that of a uniform single-phase alpha bronze structure. It is the normal aim of the sintering operation to bring about full alloying of the copper and tin, and to achieve the alpha bronze structure.

For some special bearing applications, intermediate heterogeneous copper-tin structures can be achieved by variation of the sintering conditions. A typical structure consists of tin-rich delta phase in a relatively low tin alpha bronze matrix.

The solidus temperature of 90:10 bronze is approximately 850°C., and the sintering temperatures for bronze bearings range up to 800°C. The actual sintering time need only be of the order of 5 min. at 800°C.

With regard to sintering furnace equipment, the mesh belt conveyor type of furnace has been widely adopted. Two considerations basically determine this choice, i.e. cost and technical performance. A conveyor furnace is most suitable from the economic point of view in achieving a fairly short heat-treatment cycle for a large number of items, such as characterizes bearing production.

From the technical performance aspect, the sintering operation requires careful control, and continuous equipment is most likely to achieve uniformity of heat-treatment.

For the temperature range of up to 800°C., nickel-chrome elements are adequate. Sintering atmospheres of the exothermic type are sufficient to maintain full reducing conditions, but adequate sulphur removal is quite vital in order to prevent the formation of the deleterious copper sulphide stains.

Sizing and Impregnation

Bearings are required to have a high degree of dimensional precision and, owing to the various distortions which arise during the sintering treatment, as-sintered bearings do not meet this requirement. It is normal, therefore, to apply a sizing operation after the sintering treatment in order to achieve the required dimensional precision and to improve the surface quality of the bearing. There is no significant change in density arising from the sizing operation.

Sizing operations are carried out on mechanical or hydraulic presses, and speeds of up to 3,600/hr. can be achieved with the former type of equipment.

Sizing tools are basically similar to forming tools, and comprise die, core rod, top punch and bottom punch. Although the as-sintered bearings can be dipped in oil prior to sizing, and in so doing may absorb up to 50 per cent of the pore volume, similar problems of tool wear exist as with compacting tools. Dies and core rods sustain most wear, and it will be appreciated that the amount of wear that can be tolerated is closely linked with the permitted dimensional tolerances of the finished bearing. For instance, many internal and outside diameters are required to be held to a tolerance of 0·001 in/in. or better, and it follows that permissible tool wear cannot exceed this level. It will be appreciated that tool wear problems are particularly critical for sizing tools.

Tungsten carbide is by far the most satisfactory tool material; hard chrome plate and high carbon-high chrome die steels are also used, but their performance is inferior to that of carbide.

The wear mechanism is basically one of high pressure rubbing between bearing and tool: lubricating oils somewhat reduce the friction, but oil film breakdown occurs under the heavy load conditions.

After the sizing operation, the remainder of the pores are filled with oil by the application of vacuum and heat. The use of both vacuum and heat speeds the absorption process considerably, and it is normal to fill at least 90 per cent of the pores of the bearing. It should be noted that it is not always possible to fill all the pores of the bearing since a small percentage, usually less than 2 per cent, are "blind" and are, therefore, inaccessible.

(To be concluded)

Men and Metals

A former managing director of the British Aluminium and associated companies, **Mr. George Boex,** retires from the board by rotation on May 6 next. Owing to advancing years he does not wish to seek re-election, but he will, however, continue in a consultative capacity.

At the first meeting of the newly-elected Council of the British Compressed Air Society, held at the end of last month, **Mr. W. B. Rainbird** (Climax Rock Drill and Engineering Works Limited) was elected President for the ensuing year. **Mr. E. A. Martin** (Padley and Venables Limited) was elected vice-president, and **Mr. T. C. Hore** (Holman Bros. Limited) was elected hon. technical director. The immediate past-president of the society is **Mr. G. F. Davies** (Hick, Hargreaves and Company Limited).

Retiring from the office of secretary to the Gas Council since its inception in 1948, **Mr. F. G. Brewer,** O.B.E., is to be succeeded by the chief accountant to the Council, **Mr. Wilfrid Bailey,** F.S.A.A., F.I.M.T.A. Mr. Brewer's actual retirement will take effect from September next.

It has been announced by Vickers Limited that **Captain J. A. Creed,** V.R.D. and bar, has been appointed deputy managing director of Robert Boby Limited, of Bury St. Edmunds.

A member of the Amber Group of Companies, Causeway Reinforcement Limited have announced that **Mr. Desmond Bowditch** has been appointed to the board of the company. Mr. Bowditch joined the company as general manager last year from the Henry C. Stephens Ltd. group of companies, where he was also general manager.

Among recent appointments announced to the University of Birmingham is that of **Mr. D. Kirk,** B.Sc., who is appointed Research Fellow in Industrial Metallurgy.

Chemical Engineering

TO be held in Frankfurt (Main) from May 31 to June 8, 1958, within the framework of the European Congress of Chemical Engineering, the Achema Congress 1958 has attracted about 1,000 firms as exhibiting members. The growing interest of foreign countries is also particularly marked; more than 150 firms from 14 countries will be presenting their products for discussion in the field of chemical plant and process engineering.

The detailed programme of the Achema Congress 1958, containing 32 pages, is available in the English, French and German languages, and will be forwarded free of charge on application to Dechema, Deutsche Gesellschaft für chemisches Apparatewesen, Frankfurt (Main) 7, Postfach.

Also announced by Dechema is the publication of a pamphlet, "Weighing —Laboratory Techniques," which reviews experience with all types of balances and contains a series of definitions. The price is DM.50, or DM.40 to members of Dechema.

Industrial News *Home and Overseas*

Water Treatment

An arrangement has been made whereby **Whiffen and Sons Limited** and the "Alfloc" Water Treatment Service of **Imperial Chemical Industries Limited** will co-operate in the development in the United Kingdom of the use of "Zerox" (35 per cent hydrazine solution) for the de-oxygenation of boiler feed water. Deliveries of "Zerox" and technical advice on its use will be available from Whiffen and Sons Limited or from I.C.I. sales offices.

Enquiry for Aluminium

Corrugated aluminium roofing sheets and aluminium ridge rolls 10 ft. long form the nature of an enquiry reported to the Board of Trade by the British Consulate-General at New Orleans, U.S.A. The enquiring firm is the G. H. Charbonnet Company, 330-332 Decatur Street, New Orleans, and full details of their requirements are noted with the Export Services Branch of the Board of Trade, Lacon House, Theobalds Road, London, W.C.1. Ref. E.S.B./7901/58.

Australian Copper

In its quarterly review, the Australian Bureau of Mineral Resources states that Australian exports of copper concentrates have recently been falling because of the depressed price of the metal overseas, and appear likely to remain low for some time. Production of copper in 1957 was 32,892 tons of refined and 50,881 tons of blister, compared with 29,307 tons and 49,030 tons respectively in 1956. Mine production at 13,418 tons in the third quarter, however, was 2,302 tons less than in the previous quarter. Exports for the year were 16,059 tons of concentrates and 19,181 tons of blister.

Exports of copper concentrates since July have been relatively small, and, having in mind the present position of the overseas market, the possibility of any continued large-scale shipment in the immediate months ahead appears to be remote, the review says. Australian exports of copper metal for the half-year ended December 31 were valued at £A3,116,000, compared with £A3,095,000 for the first half of 1956-57, the Commonwealth Statistician's trade figures show. Exports of copper concentrates, however, were almost halved from £A1,546,000 to £A853,000. For December only, exports fell to £A25,000, compared with £A187,000 for December, 1956.

A Provocative Talk

Referring to shop stewards as "the men of the future," Mr. Bill Kirk, the managing director of The Lawden Manufacturing Company Ltd., gave a provocative talk to **The Non-Ferrous Club** at their monthly luncheon meeting at the Queen's Hotel, Birmingham, last week. A wider appreciation of the value of the shop steward, said Mr. Kirk, and better negotiators within factories would make for greater progress and better relations everywhere.

At this meeting a collection was taken on behalf of the National Society for the Prevention of Cruelty to Children, the sum of £17 10s. 0d. being realized.

Following a brief announcement at the recent annual general meeting, plans are now in hand for the formation of a golf club for members of The Non-Ferrous Club. The annual subscription will be one guinea, and this will be used to defray the expenses of prizes, etc. A meeting is to be held at Stratford-on-Avon Golf Club on Thursday, June 26, when a morning round will be played, followed by luncheon in the club house, with a foursome match in the afternoon. Dinner has been arranged at The Welcombe Hotel, Stratford-on-Avon for the evening. Anyone interested in this meeting, or in becoming members of The Non-Ferrous Golf Club, should contact Mr. T. B. Taylor, 115 Charles Henry Street, Birmingham, 12.

Malayan Tin

Tin shipments from Singapore during March totalled 673 tons, compared with 1,162¾ tons in February, according to the Straits Trading Company. Of the March total, the United Kingdom took 25 tons, the United States 140, Europe 12, Japan 354, the Pacific 8½, India 66½, Africa ¼, Australasia 55¾, and the Middle East 11.

Tin shipments from Penang in March amounted to 2,868¼ tons, compared with 3,589 tons in February. Of the March total, the United Kingdom took 385, United Kingdom options 15, United States 1,035, Europe 509, Canada 195, Japan 85½, Pacific 14½, India 389¾, South America 100, Africa 26, Australasia 93½, and the Middle East 20.

French Requirements

French tin needs for 1958 were put at 12,000 tons by the French Minister for Industry and Commerce in a written reply to a deputy. In 1957, French tin imports totalled 11,386 tons, while local production amounted to 450 tons. Main suppliers were (in order of importance): The Netherlands, Malaya, Belgium, the United Kingdom, and West Germany.

Crucible Furnaces

An interesting little brochure has just been published by **Monometer Manufacturing Company Limited** in which this company's oil- or gas-fired crucible furnaces are dealt with. The range described and illustrated include hydraulic twin ram lip-pour tilting furnaces, centra axis manually-operated and motorized tilting furnaces, lift-out furnaces, and bale-out furnaces. Some illustrations of Monometer crucible furnace installations are also included. These units are for melting brasses, bronzes, gunmetals, aluminium, zinc alloys, magnesium, and, in fact, all non-ferrous metals. Copies of this brochure can be obtained from the company on application.

Russian Aluminium

Russia is offering little, if any, aluminium at the moment, according to trade quarters. Even if she were, it is thought that buyers would be unwilling to enter into deals until the question of the Aluminum Company of Canada's application for an anti-dumping duty on Russian metal into the United Kingdom is resolved. In 1957, the United Kingdom imported about 15,500 tons of Russian aiuminium compared with about 153,000 tons of Canadian. In 1956 and 1955, the respective figures were 197 tons and 205,036 tons, and 2,468 tons and 238,837 tons.

There were no imports of Russian aluminium in 1954. But despite the upsurge in imports during 1957, some trade quarters say that if there is a case for dumping it cannot be levelled at Russia on the price angle alone. The price at which Russia was offering metal was in line with the open world free price. Cheap offers were also reportedly emanating from a number of other countries, such as Poland, Czechoslovakia, Yugoslavia, and Formosa. In fact, it is believed that Russia sometimes refrains from offering as low as certain of the above-mentioned countries.

It is argued that now Canada has reduced her price to a more realistic level of £180 per ton, less two per cent loyalty discount, and providing cheap offers persist at a discount of more than £10, a case for dumping would appear more plausible. Some sources believe that when Russia re-enters the market her prices are unlikely to differ markedly from Canada's.

World Tin

Advance statistics issued by the International Tin Council show that production of tin-in-concentrates in Malaya during February continued to fall. Production was 3,559 tons, compared with 4,345 in January and 5,298 in December, 1957, the peak month. Nigerian production also declined to 375 tons, and Indonesian production to 1,704 tons. January production in Thailand was 751 tons, almost half the December figure. Estimated world production for 1957 (excluding the U.S.S.R.) was 173,500 tons, a drop of 2,000 tons from 1956.

Production of tin metal in the United Kingdom, which had been running at a high level since November, dropped back in February to 2,746, which was near the average monthly rate for 1957. In Belgium, in the same month, production increased to 1,000 tons.

Exports of tin-in-concentrates from the Belgian Congo showed a steady and rapid rise during the autumn of 1957, from 891 tons in August to a provisional figure of 2,191 tons in December. Bolivian exports showed a similar pattern, progressing from 1,683 tons in August to 3,750 tons in December. Exports from Indonesia in January of 967 tons showed a sharp fall from the December figure of 2,711 tons. Exports from Nigeria in January of 597 tons were also a fall from the December level.

Exports of tin metal from Malaya in February were 4,863 tons, a return to the November level after the intervening high figure for December. Belgian exports in the same month were 545 tons, showing a similar pattern. In January, exports from the Netherlands dropped slightly to 3,101 tons; those from the United Kingdom increased to 402 tons.

Imports of tin-in-concentrates into Malaya in February, at 578 tons, were down to almost a third of the December figure. Those into the United Kingdom in the same month, however, rose to 3,243 tons. In January, the Netherlands imported 2,250 tons. Belgian imports reached a peak in that month of 1,580 tons, falling in February to 496 tons. Imports of tin metal into the Netherlands

fell to 841 tons in January, and those into the United Kingdom to 2,335 tons. The total United States imports during 1957 were 56,107 tons.

Stocks of tin-in-concentrates at port in the Belgian Congo were remarkably high at the end of 1957 at 1,931 tons; while in Indonesia a high point was reached at the end of January with 3,820 tons. Stocks at Bolivian ports, after dropping to 2,048 tons at the end of January, rose again at the end of February to 2,266 tons. A similar pattern is shown by the United Kingdom smelters' stocks figures, which had risen to 3,446 tons at the end of February, but the Belgian smelters' stocks had fallen to 1,957 tons.

Stocks of tin metal in Belgium, however, were very high at 2,581 tons, and smelters' stocks in the United Kingdom, at 1,104 tons, also showed an increase.

In Full Production

An excellent recovery to full production is reported by **Griffin and George (Laboratory Construction) Ltd.,** which suffered the loss, by fire, of its Birmingham joinery works earlier this year. Following salvage operations, the company secured the use of workshop facilities which enabled them to give effective employment to some 50 of their skilled bench workers and, by "feeding" machined parts provided by friends in the industry, production was revived within one week.

We are now advised of a complete transfer to more commodious premises at Walsall Road, Perry Barr, Birmingham, and the whole of the personnel is now operating again under one roof. The group's output of scientific apparatus is not affected by the fire, for all instrument production is located at other factories in Birmingham and Mitcham, Surrey.

Contract from South Africa

It is understood from the **Head Wrightson Machine Co. Ltd.** that they are to receive an order from the South African Iron and Steel Corporation at Pretoria, valued at over £220,000, to cover the supply of a line of equipment for the cutting up of a coil of steel strip, $\frac{3}{16}$ in. thick and 54 in. wide into sheets between 4 ft. and 20 ft. long. Included in the line of equipment is a plate flattening machine of a type which has been widely used in steel works in the U.K. and overseas.

Molybdenum Lubricant Additive

An intensive selling campaign in the West country has recently been undertaken by the **Slip Group of Companies** for their anti-friction lubricant additive "Molyslip." A local press advertising scheme has been supported by a series of direct mail shots to factors and to over 3,000 stockists in the area, and visits from Slip representatives.

Welding Courses

A prospectus giving details of the courses which are being offered by the **School of Welding Technology** between April and September this year is being made available for those interested. This prospectus contains the syllabuses and other particulars of the current six courses. The response to the first series was much greater than expected, and in two cases more than 100 applications were received for the 40 available places. Applications are dealt with in order of receipt.

The courses listed are generally of the short, intensive, full-time type, but the prospectus includes the syllabus of an evening course for structural designers and draughtsmen. The Institute plans to expand its programme for both full-time and evening courses as quickly as resources permit.

Full details and copies of the prospectus may be obtained from the Institute of Welding, 54 Princes Gate, London, S.W.7.

Magnesium Applications

Full discussion of existing and future potential uses of magnesium, particularly with respect to the part which the metal and the industry may be expected to play in the jet aircraft and missiles age will be held at a Symposium on magnesium applications along this line which is being held in Los Angeles, on June 4 and 5 next, at the Institute of Aeronautical Sciences Building.

This Symposium has been organized by the Magnesium Association and the Society of Aircraft Materials and Process Engineers, and among the overseas visitors attending will be Mr. P. A. Fisher, deputy chief metallurgist of **Magnesium Elektron Limited,** of Manchester. It is understood that among the Papers to be contributed to the Symposium will be one on "Magnesium/Zirconium Alloys for Aircraft Structural Purposes, and in addi- Aircraft Structural Purposes," and in addi- Protection Measures." Both these Papers are being contributed by Mr. Fisher.

Full details of this event are available from the offices of the Magnesium Association, 122 East 42nd Street, New York 17, N.Y.

Compressed Air Society

At the annual general meeting of the **British Compressed Air Society,** held in London at the end of last month, the Council for the year 1958-59 was elected as follows:—Aerostyle Limited; Atlas Copco (G.B.) Ltd.; Broom and Wade Ltd.; Alfred Bullows and Son Ltd.; The Climax Rock Drill and Engineering Works Ltd.; Compressors Accessories Ltd.; Hick, Hargreaves and Co. Ltd.; and Padley and Venables Ltd. The associate members of the council are James Howden and Co. Ltd. and C. A. Norgren Ltd.

Corrosion Research

On Wednesday of next week, April 16, the Corrosion Group of the **Society of Chemical Industry** will hold its annual general meeting at 14 Belgrave Square, London, S.W.1, at 6.30 p.m. Following the general business meeting, the Spring Lecture will be given by Dr. W. H. J. Vernon, O.B.E., D.Sc., F.R.I.C., F.I.M., who will take as his subject "Corrosion Research and its Industrial Background."

A Retirement

After 55 years' service with the company, Mr. G. S. Andrews, chief buyer at **Ransomes Sims and Jefferies Ltd.,** has retired. Mr. Andrews, who is well known in buying circles in the steel and allied trades, has been chief buyer at Ransomes since 1924. Mr. H. H. Dawson (works director) presented Mr. Andrews with a cheque on behalf of the directors and his colleagues. Mr. Andrews is being succeeded by Mr. Peter Dorling, late of B. Elliott and Co. Ltd.

Agreement Signed

It has been announced by **Short and Mason Ltd.,** the London scientific instrument manufacturers, that they have recently signed an agreement with Aktiengesellschaft Chemisches Institut Dr. A. G. Epprecht, Zurich, whereby they will act as sole agents in Great Britain for the range of Drage instruments. An instrument application department has been set up to deal with enquiries and advise on the use and installation of the instruments, which include torsional viscometers and rheometers, also plant assemblies for automatic control of viscosity. In addition, the new Drage Multitest tensile, compression and bending test machine will be available through the London firm.

Joining of Metals Conference

Advance notice has been issued of a joining of metals conference on "The Pressure Welding of Metals," to be held at **Birmingham University** on Thursday, June 19 next. The proceedings will commence at 10 a.m. with an introductory address by Professor E. C. Rollason, head of the Department of Metallurgy at the University, and will be followed with Papers on "Industrial Practice in Cold-Pressure Welding," "Pressure Welding by Rolling," "Pressure Welding by Relative Movement Between Surfaces," and a general discussion.

Applications for enrolment forms should be addressed to the secretary, Department of Industrial Metallurgy, University of Birmingham, Edgbaston, Birmingham, 15, and marked "Pressure Welding Conference." An enrolment fee of 15s. 0d. will be charged, which will include the cost of lunch and refreshments. The last date for receipt of applications for enrolment will be Thursday, June 12.

Indian Controls

It has been reported from New Delhi that the Indian Government has announced that it has taken powers to regulate purchases and sales of non-ferrous metals—copper, lead, zinc, and tin — in different forms at prices not exceeding the landed cost by more than $3\frac{1}{2}$ per cent. In the first instance, the new order, would apply to imported copper only. However, the Government might extend the order to cover any other imported non-ferrous metals by notification.

Under the order no person should acquire or agree to acquire any non-ferrous metal except under and in accordance with a special permit issued by the Government Controller. The order would also require importers of non-ferrous metals to notify to the controller any quantity of non-ferrous metals imported or cleared on or after April 3.

Bauxite

Discovery of bauxite in the Cape York Peninsula in north Queensland seems certain to make Australia one of the major world sources of this material, says the latest report by the Australian Industries Development Association. The report says the Queensland deposits, at Weipa, run for a considerable distance north and south along the west coast of the Cape York Peninsula around Albatross Bay.

Consolidated Zinc Corporation, which discovered the bauxite deposits, has reported that very large quantities of economic grade bauxite have been indicated. The company has formed a subsidiary as a first step in development of the fields, and an agreement with the Queensland Government provides for the company to spend £A50 million on the

initial stages of development. In the first stages the company will export most of the bauxite as alumina. The company's plans include smelting alumina to aluminium at a later stage.

Bronze and Brass Founders

A meeting of members in the London and Home Counties area of the **Association of Bronze and Brass Founders** will be held on Tuesday next, April 15, at the Clarendon Restaurant, Hammersmith, London, S.W., commencing at 11.45 a.m. After luncheon at 2.15 p.m. there will be a Symposium on the cleaning and fettling of castings.

Brussels World Exhibition

Products of 87 firms in the light and medium engineering industries will be displayed on the group stand of the **Birmingham Engineering Centre** in the British Industry Pavilion at the Brussels Exhibition. The stand has been designed to display to the best advantage a collection of engineering products representative of the light and medium engineering industries.

Among the firms taking part in this display are the following: — **Acheson Colloids Ltd., Keith Blackman Ltd., Dallow Lambert and Co. Ltd., Imperial Chemical Industries Ltd. (Metals Division), Magnesium Elektron Ltd., Rapid Magnetic Machines Ltd., Delta Metal Co. Ltd., E.M.B. Company Ltd., Gibbons Bros. Ltd., McKechnie Bros. Ltd., Morgan Crucible Co. Ltd., Newman Hender and Co. Ltd., Platt Metals Ltd., Rozalex Ltd., Thermal Syndicate Ltd.,** and **Yorkshire Imperial Metals Ltd.**

Factory Equipment Exhibition

OPENING on Monday next, April 14, at Earls Court, London, the sixth Factory Equipment Exhibition will present a number of interesting productions for almost every phase of industry. The exhibition will remain open until Saturday, April 19. There will be many exhibits of interest to the metal working industries, among them being the following:—

Colt Ventilation Ltd. will feature their comprehensive industrial services, covering natural and mechanical ventilation, heating by economic oil-fired air heaters, and the fire safety venting system which can be coupled to any Colt system of industrial ventilation. Visitors to this stand will not only see the dual-purpose fire vents, operated both by fusible link to cope with a fire emergency and by manual control for daily ventilation use, but also a continuous sound film showing how the ventilators behave in a real fire, and release heat and smoke and fumes to make fire fighting easier and more successful. Colt circular or rectangular ventilated roof lights are a new addition to the company's range. These extractors are available in various sizes, with and without control dampers, to provide extra roof light and general ventilation for sedentary workers in departments where there is little or no process heat to be dealt with.

G. A. Harvey and Co. (London) Ltd. are to show equipment for the methodical storage and efficient stock control of the modern factory. This includes adjustable shelving, steel furniture, clothes lockers, and cloakroom equipment. The extensive range of "Harco" perforated metals and plastics will be shown, also a range of woven wire cloth in all meshes and gauges, in all metals, together with wire work of various kinds for domestic and industrial needs, such as machinery guards, radiator covers, pipe guards, partitions, baskets and carriers for many manufacturing processes.

Keith Blackman Ltd. This firm will be exhibiting a selection of the large quantities of various types and sizes of "Tornado" fan equipment which they hold in stock. Actually displayed will be three of the range of type APA propeller type fans for general ventilating purposes involving either foul air extraction or fresh air supply to factories and other buildings; also suited to steam and fume removal, drying work and air circulation in connection with refrigeration. Then there will also be three 10 in. dia. bifurcated fans, together with centrifugal fans, cooler fans, exhaust fans, dust exhausting and collecting unit, and a selection of industrial gas apparatus.

Minnesota Mining and Manufacturing Co. Ltd. will occupy one of the largest stands, on which will be displayed "Scotch Boy" packaging, magnetic and electrical tapes, "Scotchlite" reflective sheeting in its industrial applications, "Safety-Walk" non-slip surfacing. This latter is designed for factory floors, stairways, ramps, and gangways. This Wetordry non-slip surfacing assures protection against falls, and also increases the traction and efficiency of all power-driven equipment. A complete range of the company's electrical tapes will be shown. Improvements and modifications have been made to all these tapes in order to prove better adhesion and longer ageing qualities.

Rozalex Ltd. This Manchester company will be showing their extensive range of barrier creams, which cover most known skin hazards. Their technical research department is continuously working with industry to cope with new and anticipated dermatitis risks, and two successful results—creams Nos. 13 and 16—will be specially featured on the stand. No. 13 is stated to have proved very successful in keeping free from stains the hands of operatives using indelible spirits, duplicating inks and carbons. Cream No. 16 has a silicone base, and combines the qualities of high water repellency, low surface tension and good adherence to the skin in a non-greasy cream. The company considers it is ideal for personnel exposed repeatedly, or for long periods, to water or water-wet materials in surgical, clinical and laboratory work, as well as other similar fields.

Shell-Mex and B.P. Ltd. are staging what may be termed a complete oil fuel centre on their stand. Twenty-seven firms manufacturing industrial oil-burning equipment are co-operating with the company in displays of their latest plant, grouped round the Shell-Mex and B.P. products.

Simmonds Aerocessories Ltd., a member of the Firth Cleveland Group, is to exhibit a wide range of fasteners, nuts and tools, and there will be a selection of "Nyloc," "Fibre" and "Pinnacle" self-locking nuts in a full range of threads and sizes. Four new Surform hand tools will be shown, together with the original Surform stand plane and file. The new tools are a fine cut file, a half-round file, a block plane and a convex plane.

Parliamentary News

By Our Lobby Correspondent

Antimony Import Duty.—The Commons approved an Order increasing to a rate of 25 per cent *ad valorem* or £40 a ton, whichever was the greater, the import duty on the following antimony products: antimony metal in any form, and alloys in any form which contain not less than 85 per cent by weight of antimony; antimony oxides, and mixtures containing not less than 85 per cent by weight of antimony oxides expressed as antimony trioxide. The Order was made on March 14, and came into operation on March 21.

Moving the Order, the Minister of State, Board of Trade, Mr. J. K. Vaughan-Morgan, said that antimony metal was used for hardening lead, particularly that used in lead storage batteries, cable sheaths, bearings, type metal, and so on. An application for an increase in import duty was submitted to the Board of Trade on the ground that the existing duty was insufficient to protect the United Kingdom industry against low-priced imports coming primarily from China and, to a less extent, from Russia. After careful consideration, it appeared to them that there was undoubted evidence of significant imports of foreign antimony, at prices much below the minimum which United Kingdom smelters could economically charge, although there was every reason to believe that the industry here was as efficient as any in the world.

It seemed undesirable and unwise to allow the United Kingdom to become entirely dependent on imported supplies. The smelting of antimony was a highly specialized industry, and they did not want the value of that specialized technique to be lost to the United Kingdom. They therefore decided that the importance of affording additional protection to that small but valuable trade—probably, however, the largest in the world—against foreign competitors, outweighed the very small effect any such increase would be likely to have on the finished products in which antimony was used. They had, in every way, complied with the requirements of the G.A.T.T.

Mr. Douglas Jay (Lab., Battersea, N.) asked whether the low price at which those imports were sold here was due to their being sold below the cost of production abroad, or because the costs of production abroad were lower than those here.

Mr. Vaughan-Morgan replied that they had no information to show what the actual costs of production in the countries of origin were.

Forthcoming Meetings

April 12 — Non-Destructive Testing Society of Great Britain. Birmingham Branch. The Engineering Centre, Stephenson Place, Birmingham, 3. "Gamma Radiography." G. H. Sanders. 10.30 a.m.

April 16 — Institution of Production Engineers. Western Graduate Section. The Royal Hotel, College Green, Bristol, 1. "The Production of Metal Components by the Sintering Process." B. H. Swan. 7.30 p.m.

April 16—Society of Chemical Industry. Corrosion Group. Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. Spring Lecture: "Corrosion Research and its Industrial Background." W. H. J. Vernon. 6.30 p.m.

Metal Market News

THE recession in the United States continues to dominate the situation, and in spite of suggestions that the position is levelling off, with definite signs that the worst is over, the further increase in unemployment during March is hardly an encouraging sign. There has, of course been a good deal of talk about the rally in copper showing the way to better things and indicating that the turn of the tide has come. Probably nobody is inclined to be dogmatic about the actual trend at the moment, and it would be difficult to find a majority convinced that the recession has bottomed. As to copper as a pointer, that is not unreasonable, for the metal has always been sensitive to world affairs, and the Metal Exchange faithfully reflects the events of the day and future developments. Hence, the idea that the recent move up in copper may be taken as heralding the arrival of a better state of affairs in the economic front generally. All this may or may not be true, but the fact is that just before markets closed down for the Easter holidays it looked very much as though the upward movement had come to an end, for the end of the week brought a price fully £4 below the best level reached during the preceding days. On the Commodity Exchange, too, there were unmistakable signs that sentiment was wilting, and the close there also showed clear losses from the highest point. Undoubtedly there has been a strong speculative element behind this spectacular rally on the New York market, and its influence was sufficient to lift the custom smelters' price from 23 to 24 cents. Demand for copper, however, remains disappointing.

In Whittington Avenue last week there was a turnover of about 6,250 tons on the shorter week, for there was no trading after the midday session on Thursday, when values collapsed rather seriously on news that there were good prospects of mediation in the Chuquicamata strike which had begun on the previous Wednesday. This was, in fact, taken to mean that the trouble would probably be cleared up after the holiday, and events seem likely to confirm this view. The top of the rise was £180 and on Thursday last week the closing quotations were £175 15s. 0d. for cash and £176 three months. For two days running Wall Street had been registering losses and this did not help matters much. On balance, cash closed 30s. down and three months 25s. lower than the previous Friday. Stocks of copper in Metal Exchange warehouses were virtually unchanged at 19,407 tons. No change was seen in the producers' price at 25 cents but very poor business was reported, while the custom smelters, at 24 cents, probably fared little better. Indeed, if last week's downward trend in London is going to continue, we may confidently expect to see the smelters' quotation down before we are much older.

Tin also lost ground on a turnover of 1,575 tons, but the cash price was kept steady by Pool support and, in fact, closed above the support level at £731 10s. 0d., a gain of £1. Three months also closed above the lowest at £728 10s. 0d., which was, nevertheless, 30s. under tone the previous Friday. While demand for this metal continues to be only moderately good, there appears still to be a considerable quantity available for sale. Stocks of tin in London Metal Exchange warehouses were reported up by 538 tons at 18,465 tons, now less than 1,000 tons below the total of copper. On April 1, the American lead price was reduced by 1 cent to 12 cents, and the market turned easy here to close at £72 10s. 0d. prompt and forward, these prices showing losses of £1 7s. 6d. and 30s. on the previous Friday. The turnover was 4,075 tons. Zinc was weak in sympathy and fears of a cut in the U.S. quotation. On a turnover of 2,950 tons, losses amounted to £1 for April and 25s. for July.

New York

Aluminium and lead prices slid in the week ending April 1, creating some bustle in an otherwise featureless market. The aluminium price was cut two cents a lb., the decline being initiated by Aluminum Limited of Canada, the Canadian producer who has recently been facing intense competition from Russian selling of aluminium in Britain. The Canadian company said they were trimming the price "to make the metal more competitive with other materials." U.S. producers were forced to follow the decline, which became effective on April 1 and made the new pig aluminium price 24 cents in New York. One leading domestic producer of aluminium said it was regrettable that, because of foreign conditions, the U.S. price had to be lowered. This source indicated that U.S. cost conditions and other circumstances did not necessitate a price cut at this juncture.

A lead price reduction also came at the close of the week, the size of the price cut in this metal being a cent a lb., which made the price 12 cents a lb., New York basis. A leading custom smelter initiated the lead price cut but other leading sellers, including producers, soon followed. Intense competition here from cheaper foreign lead was cited by the initiator of the price cut as the reason for the decline. One leading producer source said the 12 cents price might mean tough conditions for some of the small and medium-sized mines who operated at higher costs than the larger producers and did not have the financial reserves to carry them through lean times. Producers were eagerly awaiting word from Washington that the Tariff Commission was ready to make its recommendations to the President for higher tariffs on lead and zinc, but no statement was made by the Commission.

Zinc continued at 10 cents a lb., although most sales were on an average price basis. Custom smelter sales in copper turned quieter after the price reached 24 cents, but custom smelters indicated they had sold substantial quantities of copper from 23 to 24 cents and were in a favourable position.

Producer copper showed little important improvement, with a slight fabricator upturn noted in magnet wire, which is used in small electrical appliances. However, this upturn at best only balanced some falling off in interest from other sectors, said trade sources, the demand from the automobile industry continuing in a depressed state.

Tin eased, reflecting the decline on foreign markets and continued light consumer demand.

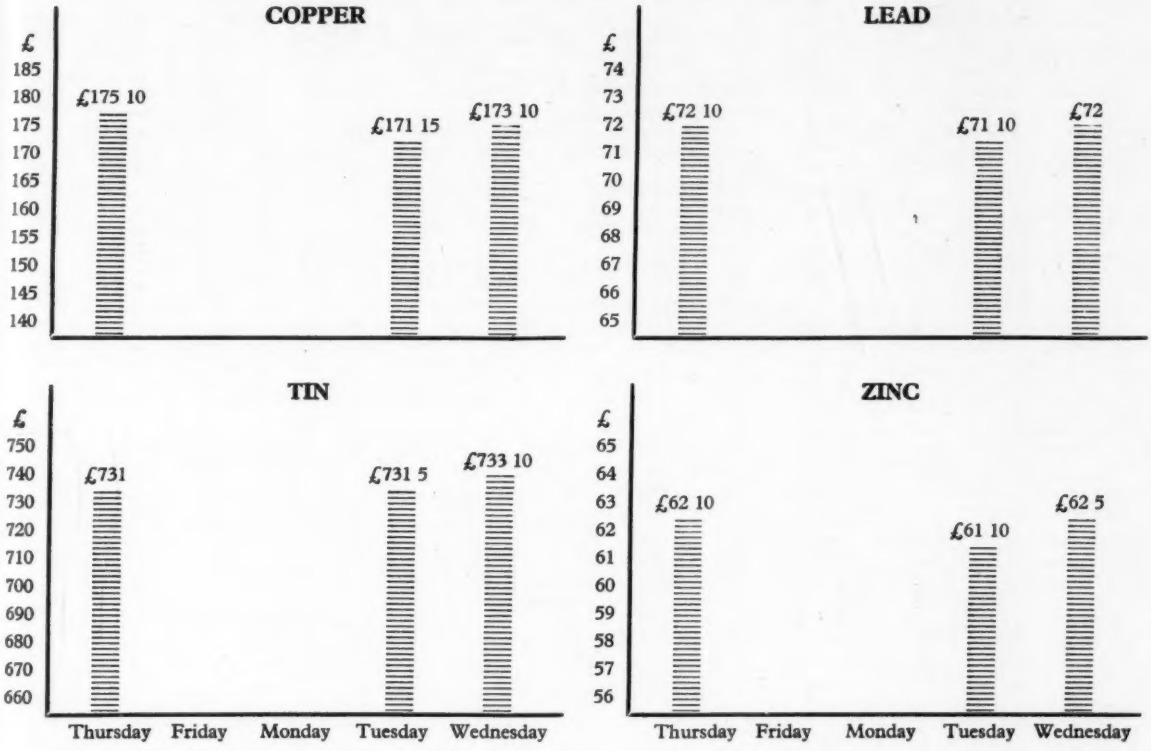
Birmingham

With orders more difficult to secure and the return of competition—after a period when virtually none existed—manufacturers are realizing that it will be difficult to maintain full capacity working. The decline in the building trade has affected makers of locks and builders' hardware. There is, however, a strong demand for locks from the motor trade. The cycle trade has suffered a setback, one reason being the recession in America, which has been a very important market. Spring sales have been delayed by cold weather.

The iron and steel trade is showing some weakness, a feature which is not surprising in view of the financial situation and the falling off in trade in other parts of the world. There has been some slowing down in the orders from structural engineers, due to the fact that they are not replacing existing building contracts which makes it necessary to keep up the flow of steel to building sites. The motor trade is still the mainstay as far as the sheet mills is concerned. Re-rollers are short of business in small bars and light angles. Active conditions prevail amongst the builders of railway rolling stock. They are engaged on substantial contracts for overseas lines. With a steadily increasing output of heavy steel plates from British sources, the balance of supply and demand is much closer than it has been for many months.

METAL PRICE CHANGES

LONDON METAL EXCHANGE, Thursday 3 April 1958 to Wednesday 9 April 1958



OVERSEAS PRICES

Latest available quotations for non-ferrous metals with approximate sterling equivalents based on current exchange rates

	Belgium fr/kg ≏ £/ton	Canada c/lb ≏ £/ton	France fr/kg ≏ £/ton	Italy lire/kg ≏ £/ton	Switzerland fr/kg ≏ £/ton	United States c/lb ≏ £/ton
Aluminium		22.50 185 17 6	210 182 15	375 217 10	2.50 209 0	26.10 208 17 6
Antimony 99.0			195 169 12 6	430 249 10		29.00 232 0
Cadmium			1,400 1,218 0	2,550 1,479 0		155.00 1,240 0
Copper						
Crude						
Wire bars 99.9				375 217 10		
Electrolytic	25.00 182 15	24.50 202 7 6	227 197 10		2.10 175 12 6	25.00 200 0
Lead		11.25 93 0	114 99 2 6	180 104 10 0	.95 79 10	12.00 96 0
Magnesium						
Nickel		71.50 590 10	1,205 104 17 6	1,330 771 10	7.80 652 5	74.00 592 0
Tin	100.25 732 17 6		885 770 0	1,410 817 17 6	8.70 727 10	92.75 742 0
Zinc						
Prime western		10.00 82 12 6				10.00 80 0
High grade 99.95		10.60 87 10 0				
High grade 99.99		11.00 90 5				
Thermic			107.12 93 2 6			
Electrolytic			115.12 100 2 6	157 91 0	.82 68 10	11.75 94 0

NON-FERROUS METAL PRICES

(All prices quoted are those available at 12 noon 9/4/58)

PRIMARY METALS

		£	s.	d.
Aluminium Ingots	ton	180	0	0
Antimony 99·6%	„	197	0	0
Antimony Metal 99%	„	190	0	0
Antimony Oxide	„	180	0	0
Antimony Sulphide Lump	„	190	0	0
Antimony Sulphide Black Powder	„	205	0	0
Arsenic	„	400	0	0
Bismuth 99·95%	lb.		16	0
Cadmium 99·9%	„		10	0
Calcium	„	2	0	0
Cerium 99%	„	13	18	0
Chromium	„		6	11
Cobalt	„		16	0
Columbite	per unit		—	
Copper H.C. Electro	ton	173	10	0
Fire Refined 99·70%	„	172	0	0
Fire Refined 99·50%	„	171	0	0
Copper Sulphate	„	66	0	0
Germanium	grm.		—	
Gold	oz.	12	9	3½
Indium	„		10	0
Iridium	„	26	0	0
Lanthanum	grm.		15	0
Lead English	ton	72	0	0
Magnesium Ingots	lb.		2	5½
Notched Bar	„		2	10½
Powder Grade 4	„		6	3
Alloy Ingot, A8 or AZ91	„		2	8
Manganese Metal	ton	300	0	0
Mercury	flask	77	0	0
Molybdenum	lb.	1	10	0
Nickel	ton	600	0	0
F. Shot	lb.		5	5
F. Ingot	„		5	6
Osmium	oz.		nom.	
Osmiridium	„		nom.	
Palladium	„	7	10	0
Platinum	„	26	15	0
Rhodium	„	40	0	0
Ruthenium	„	16	0	0
Selenium	lb.		nom.	
Silicon 98%	ton		nom.	
Silver Spot Bars	oz.		6	4
Tellurium	lb.		15	0
Tin	ton	733	10	0
***Zinc**				
Electrolytic	ton		—	
Min 99·99%	„		—	
Virgin Min 98%	„	62	2	6
Dust 95/97%	„	104	0	0
Dust 98/99%	„	110	0	0
Granulated 99+%	„	87	2	6
Granulated 99·99+%	„	100	2	6

**Duty and Carriage to customers' works for buyers' account.*

INGOT METALS

Aluminium Alloy (Virgin)	£	s.	d.
B.S. 1490 L.M.5 ton	210	0	0
B.S. 1490 L.M.6 „	202	0	0
B.S. 1490 L.M.7 „	216	0	0
B.S. 1490 L.M.8 „	203	0	0
B.S. 1490 L.M.9 „	203	0	0
B.S. 1490 L.M.10 „	221	0	0
B.S. 1490 L.M.11 „	215	0	0
B.S. 1490 L.M.12 „	223	0	0
B.S. 1490 L.M.13 „	216	0	0
B.S. 1490 L.M.14 „	224	0	0
B.S. 1490 L.M.15 „	210	0	0
B.S. 1490 L.M.16 „	206	0	0
B.S. 1490 L.M.18 „	203	0	0
B.S. 1490 L.M.22 „	210	0	0

		£	s.	d.
†**Aluminium Alloy (Secondary)**				
B.S. 1490 L.M.1 ton		155	0	0
B.S. 1490 L.M.2 „		161	10	0
B.S. 1490 L.M.4 „		182	10	0
B.S. 1490 L.M.6 „		204	10	0
†Average selling prices for February				
***Aluminium Bronze**				
BSS 1400 AB.1	ton	203	0	0
BSS 1400 AB.2	„	225	0	0
***Brass**				
BSS 1400-B3 65/35	„	129	0	0
BSS 249	„		—	
BSS 1400-B6 85/15	„		—	
***Gunmetal**				
R.C.H. 3/4% ton	ton		—	
(85/5/5/5)	„	156	0	0
(86/7/5/2)	„	166	0	0
(88/10/2/1)	„		—	
(88/10/2/½)	„		—	
Manganese Bronze				
BSS 1400 HTB1	„		—	
BSS 1400 HTB2	„		—	
BSS 1400 HTB3	„		—	
Nickel Silver				
Casting Quality 12%	„		nom.	
„ „ 16%	„		nom.	
„ „ 18%	„		nom.	
***Phosphor Bronze**				
2B8 guaranteed A.I.D. released	„	240	0	0
Phosphor Copper				
10%	„	210	0	0
15%	„	218	0	0

**Average prices for the last week-end.*

Phosphor Tin				
5%	ton		—	
Silicon Bronze				
BSS 1400-SB1	„		—	
Solder, soft, BSS 219				
Grade C Tinmans	„	345	0	0
Grade D Plumbers	„	279	0	0
Grade M	„	378	0	0
Solder, Brazing, BSS 1845				
Type 8 (Granulated)	lb.		—	
Type 9 „	„		—	
Zinc Alloys				
Mazak III	ton	93	7	6
Mazak V	„	97	7	6
Kayem	„	103	7	6
Kayem II	„	109	7	6
Sodium-Zinc	lb.		2	5

SEMI-FABRICATED PRODUCTS

Prices of all semi-fabricated products vary according to dimensions and quantities. The following are the basis prices for certain specific products.

Aluminium		£	s.	d.
Sheet 10 S.W.G.	lb.		2	8
Sheet 18 S.W.G.	„		2	10
Sheet 24 S.W.G.	„		3	1
Strip 10 S.W.G.	„		2	8
Strip 18 S.W.G.	„		2	9
Strip 24 S.W.G.	„		2	10½
Circles 22 S.W.G.	„		3	2
Circles 18 S.W.G.	„		3	1
Circles 12 S.W.G.	„		3	0
Plate as rolled	„		2	7½
Sections	„		3	1½
Wire 10 S.W.G.	„		2	11
Tubes 1 in. o.d. 16 S.W.G.	„		4	0

		£	s.	d.
Aluminium Alloys				
BS1470. HS10W.	lb.			
Sheet 10 S.W.G.	„		3	0½
Sheet 18 S.W.G.	„		3	3
Sheet 24 S.W.G.	„		3	10½
Strip 10 S.W.G.	„		3	0½
Strip 18 S.W.G.	„		3	2
Strip 24 S.W.G.	„		3	10
BS1477 HP30M. Plate as rolled			2	10½
BS1470. HC15WP.				
Sheet 10 S.W.G.	lb.		3	6½
Sheet 18 S.W.G.	„		4	0½
Sheet 24 S.W.G.	„		4	10½
Strip 10 S.W.G.	„		3	9½
Strip 18 S.W.G.	„		4	0½
Strip 24 S.W.G.	„		4	8
BS1477. HPC15WP. Plate heat treated	„		3	5½
BS1475. HG10W. Wire 10 S.W.G.	„		3	9½
BS1471. HT10WP Tubes 1 in. o.d. 16 S.W.G.	„		4	11
BS1476. HE10WP. Sections	„		3	1
Beryllium Copper				
Strip	„	1	4	11
Rod	„	1	1	6
Wire	„	1	4	9
Brass Tubes	„		1	4½
Brazed Tubes	„		—	
Drawn Strip Sections	„		—	
Sheet	ton		—	
Strip	„	207	0	0
Extruded Bar	lb.		1	8½
Extruded Bar (Pure Metal Basis)	„		—	
Condenser Plate (Yellow Metal)	ton	148	0	0
Condenser Plate (Naval Brass)	„	158	0	0
Wire	lb.		2	2½
Copper Tubes	lb.		1	8½
Sheet	ton	205	5	0
Strip	„	205	5	0
Plain Plates	„		—	
Locomotive Rods	„		—	
H.C. Wire	„	226	5	0
Cupro Nickel Tubes 70/30	lb.		3	2½
Lead Pipes (London)	ton	115	5	0
Sheets (London)	„	113	0	0
Tellurium Lead	„	£6 extra		
Nickel Silver				
Sheet and Strip 7%	„		3	3
Wire 10%	„		3	9½
Phosphor Bronze Wire	„		3	6½
Titanium (10,000 lb. lots)				
Billet 11″-4″	lb.	69/-	60/-	
Wire ·315″-·036″	„	101/-	201/-	
Sheet (4′/8′×2′) ·160″-·010″	„	100/-	158/-	
Strip ·048″-·003″	„	100/-	350/-	
Tube Representative gauge	„	320/-		
Extrusions	„	137/-		
Zinc Sheets, English destinations	ton	98	0	0
Strip	„	nom.		

Scrap Metal Prices

Merchants' average buying prices delivered, per ton, 8/4/58.

	£
Aluminium	
New Cuttings	150
Old Rolled	120
Segregated Turnings	87
Brass	
Cuttings	112
Rod Ends	109
Heavy Yellow	95
Light	90
Rolled	104
Collected Scrap	94
Turnings	104
Copper	
Wire	150
Firebox, cut up	150
Heavy	145
Light	140
Cuttings	150
Turnings	137
Braziery	117
Gunmetal	
Gear Wheels	147
Admiralty	147
Commercial	124
Turnings	119
Lead	
Scrap	62/5
Nickel	
Cuttings	—
Anodes	525
Phosphor Bronze	
Scrap	124
Turnings	119
Zinc	
Remelted	—
Cuttings	42
Old Zinc	30

The latest available scrap prices quoted on foreign markets are as follow. (The figures in brackets give the English equivalents in £1 per ton):—

West Germany (D-marks per 100 kilos):		
Used copper wire	(£156.12.6)	180
Heavy copper	(£152.5.0)	175
Light copper	(£130.10.0)	150
Heavy brass	(£100.0.0)	115
Light brass	(£69.12.6)	80
Soft lead scrap	(£61.0.0)	70
Zinc scrap	(£39.2.6)	45
Used aluminium unsorted	(£87.0.0)	100
France (francs per kilo):		
Copper	(£204.10.0)	235
Heavy copper	(£204.10.0)	235
Light brass	(£148.0.0)	170
Zinc castings	(£67.0.0)	77
Tin	(£565.10.0)	650
Aluminium pans (98½ per cent)	(£130.10.0)	150
Italy (lire per kilo):		
Aluminium soft sheet clippings (new)	(£188.10.0)	325
Aluminium copper alloy	(£101.10.0)	175
Lead, soft, first quality	(£85.5.0)	147
Lead, battery plates	(£50.10.0)	87
Copper, first grade	(£174.0.0)	300
Copper, second grade	(£162.10.0)	280
Bronze, first quality machinery	(£177.0.0)	305
Bronze, commercial gunmetal	(£148.0.0)	255
Brass, heavy	(£124.15.0)	215
Brass, light	(£113.2.6)	195
Brass, bar turnings	(£127.12.6)	220
New zinc sheet clippings	(£55.2.6)	95
Old zinc	(£40.12.6)	70

Financial News

Enfield Rolling Mills Ltd.

Group trading profit £1,685,424 (£1,495,129). Net profit £630,650 (£531,474). Final dividend of 10 per cent recommended, making 12½ per cent for the year.

Amber Chemical Industries

Group profit, 1957, £17,472 (loss £34,102), subject to tax of £968 (£143 adjustment), of which £1,085 (£356) attributable to outside shareholders. Off subsidiary preliminary expenses £186 (nil). Preference dividend for year 1953 £2,875 (nil), debit forward £71,803 (£84,161). Current assets £199,887 (£152,409), and liabilities £109,750 (£88,263).

Elkington and Co. Ltd.

Dividend 5 per cent for 1957 (nil). Group profit £78,158 (£13,260) before tax of £6,600 (£4,000). Add profit on sale of fixed assets nil (£135,638). Costs of re-organization and development nil (£50,000). To general reserve £50,000 (nil). Forward £13,160 (£10,577).

New Companies

The particulars of companies recently registered are quoted from the daily register compiled by Jordan and Sons Limited, Company Registration Agents, Chancery Lane, W.C.2.

George Cohen 600 Group (Overseas) Limited (599171). Registered February 20, 1958. To carry on business of an investment holding company; iron, steel, metal and machinery merchants, civil engineers, etc. Nominal capital, £150,000 in £1 shares. Directors not stated.

Shirland Metals Limited (599218), 6 Shirland Mews, W.9. Registered February 20, 1958. To carry on business of precision, construction and chemical engineers, tool makers, etc. Nominal capital, £1,000 in £1 shares. Directors: Rudolph Lenk and Geo. Bertl.

Rowmill Metals Limited (599428). Registered February 25, 1958. To take over business of dealers in non-ferrous metals carried on at Mount Street, Nechells, Birmingham, by R.M. (Metals) Ltd., etc. Nominal capital, £100 in £1 shares. Directors: Thomas Miller, Stanley G. Morgan and Harold Burke.

Trade Publications

Fire Protection.—Fire Offices' Committee Fire Protection Association, 15 Queen Street, London, E.C.4.

The latest issue of the Fire Protection Bulletin deals with the dangers that can arise from inflammable liquids, and lists some of the many accidents that can happen from the mishandling of such liquids, and gives some actual incidents involving fatalities.

Keebush Diaphragm Pump. — Kestner Evaporator and Engineering Co. Ltd., 5 Grosvenor Gardens, London, S.W.1.

Leaflet No. 301 has as its subject details of the Keebush diaphragm pump. In this pump, which is glandless, self-priming and suitable for acids and acid slurries, the body is of Keebush synthetic resin, and the diaphragm and ball valves of synthetic rubber and flexible plastics.

Electric Resistance Heated Bell Furnaces. —G.W.B. Furnaces Ltd., P.O. Box No. 4, Dibdale Works, Dudley, Worcs.

This is an eight-page brochure in colour which sets out the very wide application which this type of installation has. Bell furnaces are used for such varied processes as stress relieving, sintering, nitriding, malleableizing, brazing, and the like. One of the most common applications is in the field of annealing, particularly bright annealing under a protective atmosphere. A number of illustrations are given showing furnaces installed.

Flow Indicators. — Walker, Crosweller and Company Ltd., Cheltenham, Glos.

A new comprehensive pamphlet has just been issued by this company illustrating their "Arkon" flow indicators. Incorporated are their latest indicators (sizes ½ in. to 1 in.), which can be adjusted for high or low velocities of flow. These indicators are used to show the flow of cooling water, lubricating oil, cooling oil, gas or air, etc. In addition to photographs, charts and diagrams are included in the pamphlet.

Electrical Products —The English Electric Company Limited, Foregate Street, Stafford.

Five new publications have just been issued, covering the "English Electric" metalclad and oil-filled circuit breakers, control switches, indicating lamps, and current transformers. Photographs and diagrams are included in each case to reinforce the descriptive text.

Lubricants.—Joseph Batson and Company Ltd., Tiptone Works, Tipton, Staffs.

Two new leaflets are published describing Tiptone Dielubes and Lubricant Dispensing equipment, and their efficient application in the metal-working industries. The automatic lubricating dispensing equipment has press-button control, and details are also given of hand-operated equipment. The Tiptone Dielubes for hot or cold metal-working operations are also illustrated, and data given.

Overhead Travelling Cranes. — Lifting Equipment Ltd., Chittening Estate, Avonmouth, Bristol.

In this 20-page booklet, various types of overhead travelling cranes, electric hoists, jib cranes, plant hoists, and other special equipment are described in detail, together with operational data and illustrations.

THE STOCK EXCHANGE

Steady But Quiet Conditions Throughout The Industrial Market

ISSUED CAPITAL •	AMOUNT OF SHARE	NAME OF COMPANY	MIDDLE PRICE 8 APRIL	+RISE —FALL	DIV. FOR LAST FIN. YEAR	DIV. FOR PREV. YEAR	DIV. YIELD	1958 HIGH	1958 LOW	1957 HIGH	1957 LOW
£	£				Per cent	Per cent					
4,435,792	1	Amalgamated Metal Corporation ...	18/6		10	10	10 16 3	19/9	17/9	28/3	18/–
400,000	2/–	Anti-Attrition Metal	1/6		8½	7½	11 6 9	1/6	1/3	2/6	1/6
33,639,483	Stk. (£1)	Associated Electrical Industries ...	48/3	—9d.	15	15	6 4 3	51/–	47/–	72/3	47/9
1,590,000	1	Birfield Industries	49/6		15	20N	6 1 3	53/9	49/6	70/–	48/9
3,196,667	1	Birmid Industries	57/9	+1/3	17½	17½	6 1 9	57/9	56/3	80/6	55/9
5,630,344	Stk. (£1)	Birmingham Small Arms	24/3	+4½d.	10	8	8 5 0	26/7½	23/9	33/–	21/9
203,150	Stk. (£1)	Ditto Cum. A. Pref. 5%	15/7½		5	5	6 8 0	15/7½	14/7½	16/–	15/–
350,580	Stk. (£1)	Ditto Cum. B. Pref. 6%	16/10½		6	6	7 2 3	17/–	16/6	19/–	16/6
500,000	1	Bolton (Thos.) & Sons	26/10½		12½	12½	9 6 0	28/9	26/10½	30/3	28/9
300,000	1	Ditto Pref. 5%	15/6		5	5	6 9 0		—	16/9	14/3
160,000	1	Booth (James) & Co. Cum. Pref. 7%	19/3		7	7	7 5 6	19/3	19/–	22/3	18/9
9,000,000	Stk. (£1)	British Aluminium Co.	45/–		12	12	5 6 9	46/6	41/3	72/–	38/3
1,500,000	Stk. (£1)	Ditto Pref. 6%	19/–	+3d.	6	6	6 6 3	19/3	18/4½	21/6	18/–
15,000,000	Stk. (£1)	British Insulated Callender's Cables	41/3	+6d.	12½	12½	6 1 3	42/–	38/10½	55/–	40/–
17,047,166	Stk. (£1)	British Oxygen Co. Ltd., Ord ...	34/3		10	10	5 16 9	34/6	29/–	39/–	29/6
600,000	Stk. (5/–)	Canning (W.) & Co.	21/–		25	25	5 19 0	21/–	20/1½	24/6	19/3
60,484	1/–	Carr (Chas.)	2/1½	—1½d.	25	25	X8 4 9	2/3	2/–	3/6	2/1½
150,000	2/–	Case (Alfred) & Co. Ltd.	4/4½		25	25	11 8 6	4/9	4/4½	4/6	4/–
555,000	1	Clifford (Chas.) Ltd.	16/4½		10	10	12 4 3	16/6	16/–	20/6	15/9
45,000	1	Ditto Cum. Pref. 6%	15/10½		6	6	7 11 3		—	17/6	16/–
250,000	2/–	Coley Metals	3/3		25	25	15 7 9	4/6	3/3	5/7½	3/9
8,730,596	1	Cons. Zinc Corp.†	46/6	—6d.	22½	22½	9 13 6	51/6	43/–	92/6	49/–
1,136,233	1	Davy & United	45/9	—6d.	15	12½	6 11 3	48/–	45/9	60/6	42/6
2,750,000	5/–	Delta Metal	19/6	—1½d.	30	•17½	7 13 9	21/4½	19/6	28/6	19/–
4,160,000	Stk. (£1)	Enfield Rolling Mills Ltd.	30/6	+3/–	15B	22½	8 4 0	30/6	24/–	38/6	25/–
500,000	1	Evered & Co.	39/–		15	15	7 13 9	41/3	39/–	52/9	42/–
18,000,000	Stk. (£1)	General Electric Co.	30/6		12½	14	Y 7 10 9	38/7½	29/6	59/–	38/–
1,250,000	Stk. (10/–)	General Refractories Ltd.	33/9	+1/–	20	17½	5 18 6	33/9	27/3	37/–	26/9
401,240	1	Gibbons (Dudley) Ltd.	65/–	—6d.	15	12	4 12 3	66/3	64/–	71/–	53/–
750,000	5/–	Glacier Metal Co. Ltd.	6/–		11½	11½	9 11 9	6/–	5/7½	8/1½	5/10½
1,750,000	5/–	Glynwed Tubes	13/6		20	20	7 8 3	13/6	12/10½	18/–	12/6
5,421,049	10/–	Goodlass Wall & Lead Industries ...	20/3xcap	+3d.	18Z	16	5 18 6	20/3	19/3	37/3	28/9
342,195	1	Greenwood & Batley	46/9	+6d.	17½	17½	7 9 9	46/10½	45/–	50/–	46/–
396,000	5/–	Harrison (B'ham) Ord.	12/4½		•15	•30‡	6 1 3	12/4½	11/6	16/9	12/4½
150,000	1	Ditto Cum. Pref. 7%	18/9		7	7	7 9 3		—	22/3	18/7½
1,075,167	5/–	Heenan Group	7/1½		10	20‡	7 0 3	7/7½	6/9	10/4½	6/9
142,045,750	Stk. (£1)	Imperial Chemical Industries ...	43/9	—3d.	12Z	10	5 9 9	44/1½	36/6	46/6	36/3
33,708,769	Stk. (£1)	Ditto Cum. Pref. 5%	16/–	—3d.	5	5	6 5 0	17/1½	16/–	18/6	15/6
14,584,025	••	International Nickel	136	—2½	$3.75	$3.75	4 19 6	144½	136	222	130
430,000	5/–	Jenks (E. P.), Ltd.	6/9xcap	—3d.	27½ ϕ	27½	10 3 9	7/9½	6/9	18/10½	15/1½
300,000	1	Johnson, Matthey & Co. Cum. Pref. 5%	16/3		5	5	6 3 0	16/3	15/–	17/–	14/6
3,987,435	1	Ditto Ord.	39/6		10	9	5 1 3	41/3	37/6	58/9	40/–
600,000	10/–	Keith, Blackman	16/3		15	15	9 4 6	16/3	15/–	21/9	15/–
160,000	4/–	London Aluminium	3/1½		10	5	12 16 0	4/3	3/1½	6/9	3/6
2,400,000	1	London Elec. Wire & Smith's Ord....	43/–	+1/3	12½	12½	5 16 3	43/–	39/9	54/6	41/–
400,000	1	Ditto Pref.	22/9	+6d.	7½	7½	6 11 9	22/9	22/3	25/3	21/9
765,012	1	McKechnie Brothers Ord.	35/–		15	15	8 11 6		—	48/9	37/6
1,530,024	1	Ditto A Ord.	32/6		15	15	9 4 6		—	47/6	36/–
1,108,268	5/–	Manganese Bronze & Brass	10/3		27½‡	25	6 14 3	10/3	9/–	21/10½	7/6
50,628	6/–	Ditto (7½% N.C. Pref.)	6/–		7½	7½	7 10 0	6/–	5/9	6/6	5/–
13,098,855	Stk. (£1)	Metal Box	46/9		20‡	15M	4 5 6	46/9	41/9	59/–	40/3
415,760	Stk. (2/–)	Metal Traders	6/6		50	50	15 7 9	6/6	6/3	8/–	6/3
160,000	1	Mint (The) Birmingham	21/9		10	10	9 4 0	22/9	21/9	25/–	21/6
80,000	5	Ditto Pref. 6%	83/6		6	6	7 3 9		—	90/6	83/6
3,064,930	Stk. (£1)	Morgan Crucible A	39/–		10	11	5 2 6	40/–	34/–	54/–	35/–
1,000,000	Stk. (£1)	Ditto 5½% Cum. 1st Pref. ...	17/–		5½	5½	6 9 6	17/3	17/–	19/3	16/–
2,200,000	Stk. (£1)	Murex	53/6		20	20	7 9 6	57/6	53/6	79/9	57/–
468,000	5/–	Ratcliffs (Great Bridge)	7/3		10	10	6 19 0	7/3	6/10½	8/–	6/10½
234,960	10/–	Sanderson Bros. & Newbould ...	27/–		27½D	27½	6 15 9	27/–	26/–	41/–	24/9
1,365,000	Stk. (5/–)	Serck Radiators	11/6		17½Z	15	5 1 6	12/–	11/–	18/10½	11/6
600,400	Stk. (£1)	Stone (J.) & Co. (Holdings)	43/9		16	16	7 6 6		—	57/6	43/9
600,000	1	Ditto Cum. Pref. 6½%	20/–		6½	6½	6 10 0		—	21/9	18/9
14,494,862	Stk. (£1)	Tube Investments Ord.	53/6	+9d.	15	15	5 12 3	53/9	48/4½	70/9	50/6
41,000,000	Stk. (£1)	Vickers	30/–		10	10	6 13 3	31/–	29/4½	46/–	29/–
750,000	Stk. (£1)	Ditto Pref. 5%	15/6		5	5	6 9 0	15/6	14/9	18/–	14/–
6,863,807	Stk. (£1)	Ditto Pref. 5% tax free	22/–		•5	•5	6 19 9A	23/–	21/3	24/9	20/7½
2,200,000	1	Ward (Thos. W.), Ord.	75/3	+3d.	20	15	5 6 3	75/6	70/9	83/–	64/–
2,666,024	Stk. (£1)	Westinghouse Brake	36/6	+3d.	10	18P	5 9 6	36/6	32/6	85/–	29/1½
225,000	2/–	Wolverhampton Die-Casting ...	7/10½	—1½d.	25	40	6 7 0	8/–	7/2½	10/1½	7/–
591,000	5/–	Wolverhampton Metal	16/1½	+9d.	27½	27½	8 10 6	16/1½	16/–	22/3	14/9
78,465	2/6	Wright, Bindley & Gell	3/3		20	17½E	15 7 9	3/9½	3/3	3/9	2/7½
124,140	1	Ditto Cum. Pref. 6%	11/6		6	6	10 8 9		—	12/6	11/3
150,000	1/–	Zinc Alloy Rust Proof	2/10½		40D	33½	9 5 6	3/1½	2/7½	5/–	2/9

•Dividend paid free of Income Tax. †Incorporating Zinc Corpn. & Imperial Smelting ••Shares of no Par Value. ‡ and 100% Capitalized issue. • The figures given relate to the issue quoted in the third column. A Calculated on £7 14 6 gross. H and 200% capitalized issue. M and 10% capitalized issue. Y Calculated on 11½% dividend. ||Adjusted to allow for capitalization issue. E for 15 months. P and 100% capitalized issue, also "rights" issue of 2 new shares at 35/– per share or £3 stock held. D and 50% capitalized issue. Z and 50% capitalized issue. B equivalent to 12½% on existing Ordinary Capital after 100% capitalized issue. ϕ And 100% capitalized issue. X Calculated on 17½%.